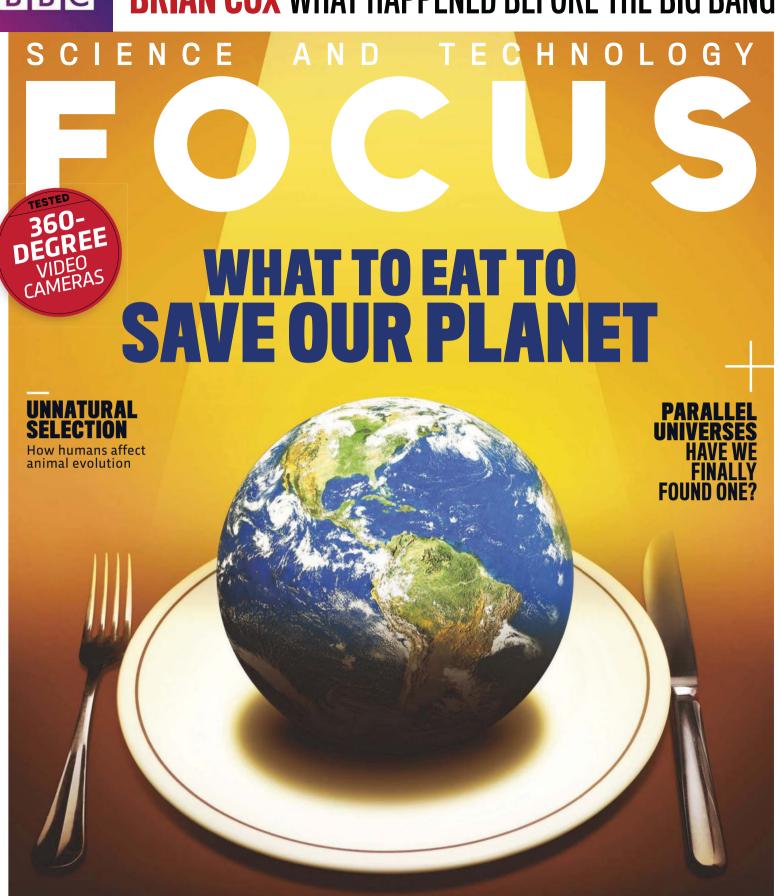


BRIAN COX WHAT HAPPENED BEFORE THE BIG BANG



Plus

THE CREATURE THAT WILL TEACH US TO BEAT CANCER, AGEING AND PAIN

What we can learn from the naked mole rat



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WHAT WE'VE FOUND **OUT THIS MONTH**

> Plants can get cancer → p80

WELCOME



The BBC Focus team is obsessed with food, and like many offices, biscuits occupy a special place in our hearts and on our desks. There is no unanimous favourite though. In fact, ask the team what their favourite biscuit is and you'll see a mild-mannered bunch become a shouty and sweary group of louts in about five minutes flat. The one thing we do agree on though, is that we eat too much meat. Whether it's the ethics or the ecology, we all

think we should lay off the bacon. So what diet really is best for the planet? If we became better people tomorrow, and packed in the meateating to become vegan or vegetarian, would planet Earth be better off? Josh Gabbatiss dives in to the science on p42.

On a cheerier note, summer is here. If you're heading overseas for your holiday, then you might want to check out Helen Czerski's column on p77 – it's all about turbulence. Every time it strikes, I grab the arms of my seat and my palms sweat, a lot. But knowledge is power, they say, and I'm hoping that my newfound understanding of this phenomena will make my next flight a little less sweaty.

Finally, this issue offers up the final instalment of our four-part guide to the Universe, written by Brian Cox and Jeff Forshaw (p68), Of course I'm biased, but it's been one of the most succinct and eloquent guides to physics I've ever read. If you've missed out on any part of the series, you can order back issues by visiting buysubscriptions.com/ focusbackissues, or by phoning 01795 414 699.

Enjoy the issue!



Daniel Bennett, Editor

IN THIS ISSUE

KAT ARNEY

Kat's background is in genetics and biology. As a presenter on the Naked Scientists podcast, she's also ideally placed to investigate naked mole rats! → p50



JULES HOWARD

Zoologist Jules researches the relationship between humans and animals. He takes a look at how we're affecting the evolution of other species. → p58



CARLOS MAGDALENA

Based at Kew Gardens, Carlos's work to save rare plant species from extinction has earned him the nickname of 'The Plant Messiah'. → p92

CONTACT US

Advertising

We live in a unique

astronomical

epoch that

allows us to

study the Big Bang →p68

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WANT MORE? FOLLOW **SCIENCEFOCUS**

In China, revellers celebrate a 500-year-old tradition by

hurling molten iron into the $air \rightarrow p10$

Raw milk cheeses

could be fuelling antibiotic

resistance → p21

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CONTENTS

32



REGULARS

10 Eye opener

15 **Discoveries**

All of this month's biggest science news.

29 Innovations

Feast your eyes on this month's coolest tech. PLUS: 360° cameras on test.

39 **Reply**All your letters and emails.

77 Helen Czerski

Hate turbulence? Strap yourself in to find out why it happens.

79 **0&A**

How do microbeads affect fish? Could you walk on a neutron star? Can eating a lot of sugar lead to diabetes? These questions and many more answered this month.

90 Out there

All the best science-y stuff to do this month.

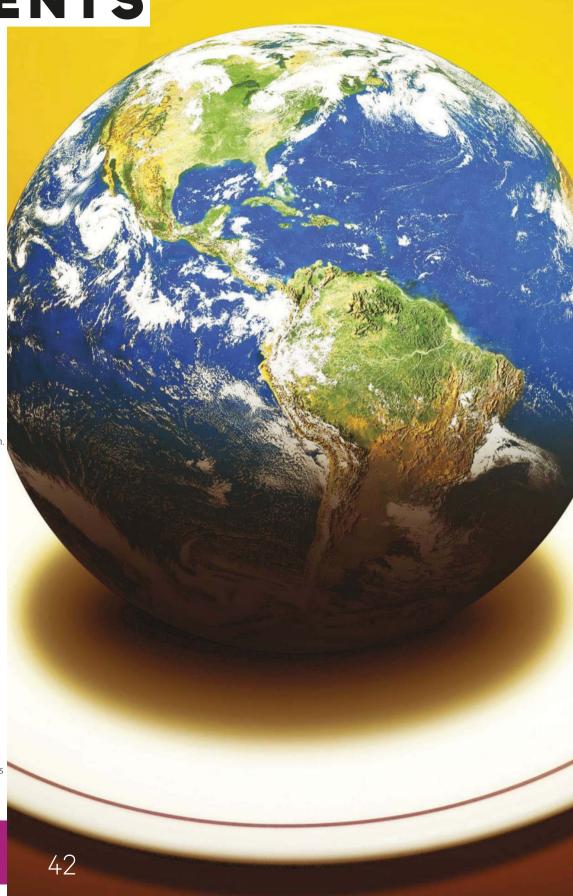
$96\,\text{Crossword}$

Give your brain a workout.

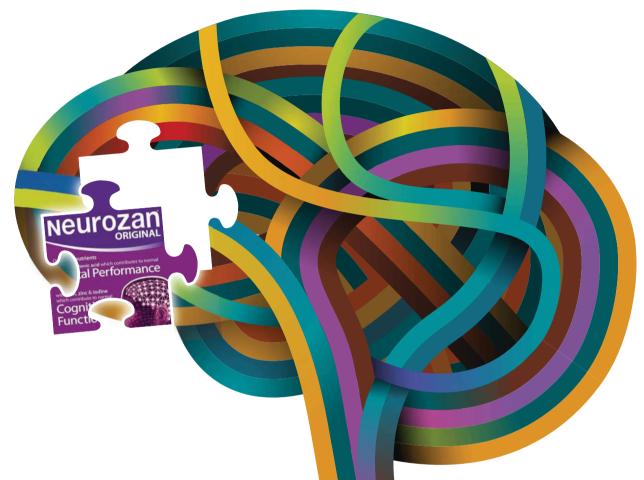
98 **My life scientific** Helen Pilcher talks lava, explosions and bandits with volcanologist Prof Tamsin Mather.

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FEATURES

Reader survey

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What to eat to save the planet

Could a vegan diet be better for the environment, or should we keep tucking into burgers?

The naked mole rat's guide to eternal life

These sabre-toothed sausages have many secrets up their wrinkly sleeves.

Unnatural selection

Climate change, urbanisation and poaching are having a surprising impact on some of our planet's animal life.

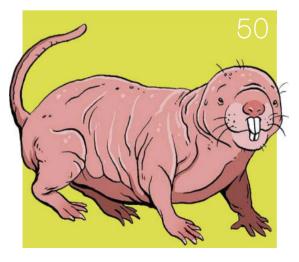
Digging for electricity

Could the lithium mines of Bolivia be the site of the next 'gold rush'?

Jeff Forshaw and Brian Cox's guide to the cosmos

In the final part of our exclusive series, Jeff Forshaw and Brian Cox investigate the start of space, time and everything.





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Can't wait until next month to get your fix of science and tech? The Science Focus website is packed with news, articles and Q&As to keep your brain satisfied. sciencefocus.com



Special issue



ANSWERS TO LIFE'S BIG QUESTIONS

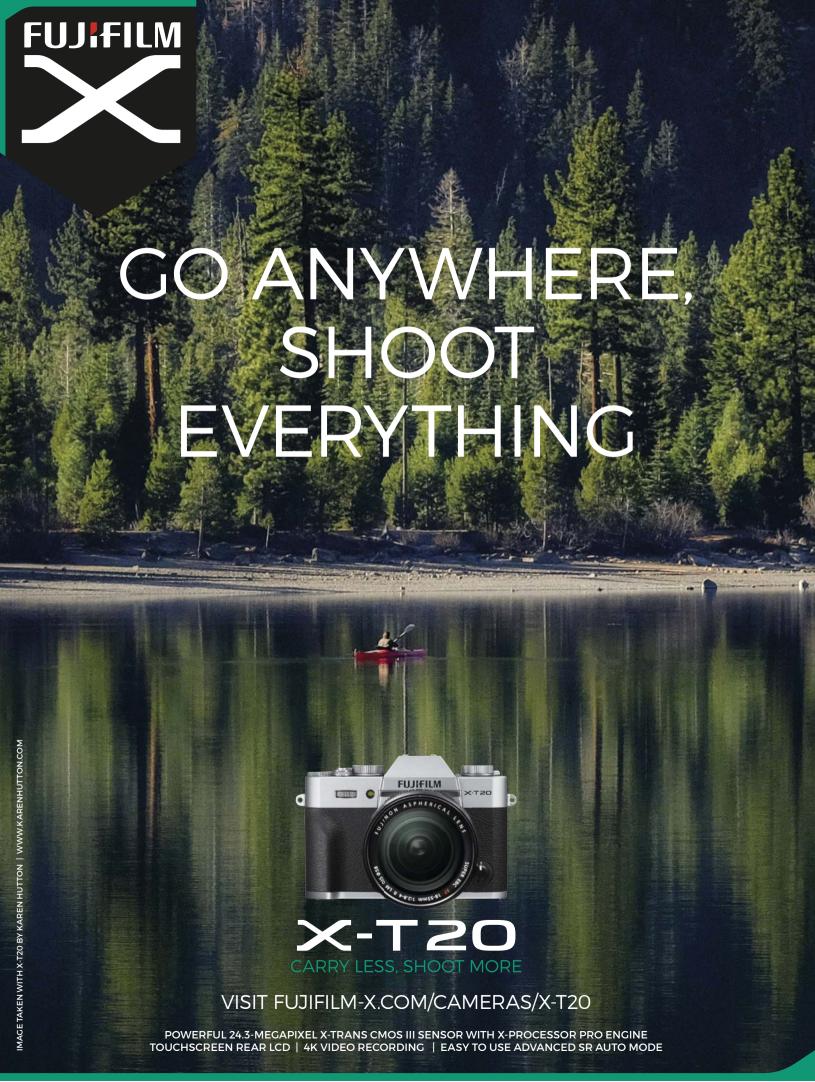
This special issue explores the incredible science of everyday life. Find out what fish drink, why we forget and much more.





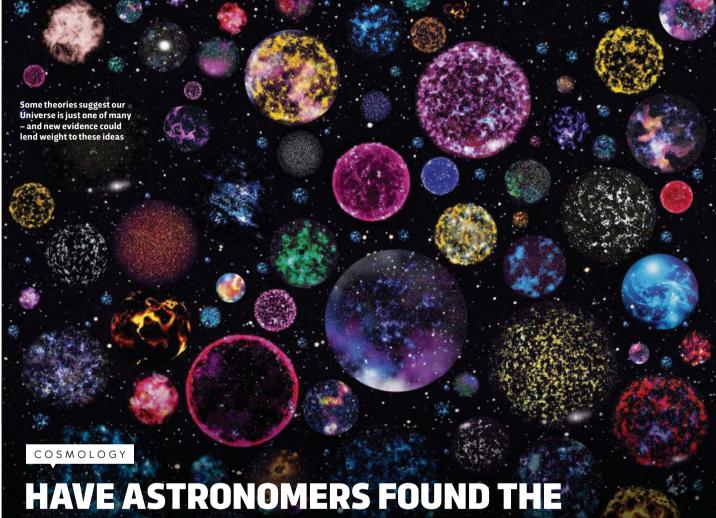






DISCOVERIES DISPATCHES FROM THE CUTTING EDGE

JULY 2017 EDITED BY JASON GOODYER



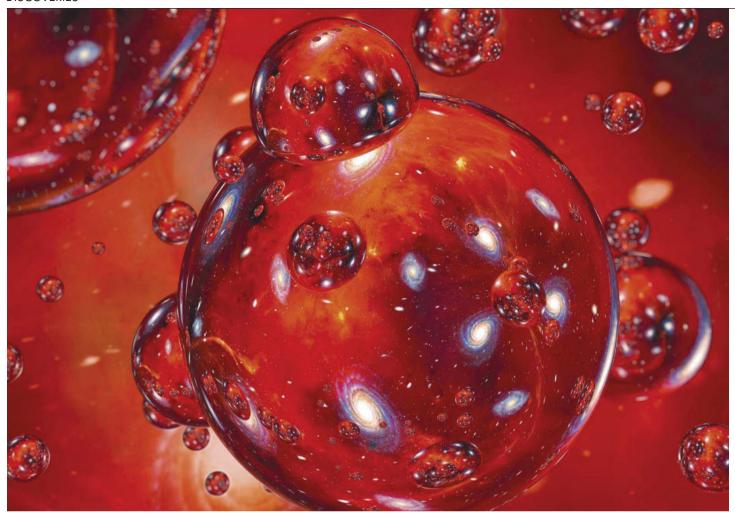
FIRST EVIDENCE OF THE MULTIVERSE?

'Cold Spot' found in the cosmic microwave background may have been caused by our Universe colliding with another

It's a trippy thought: somewhere, in a parallel universe, a version of you is the prime minister. In another parallel universe you're a pop star, and in another you're a Nobel Prize-winning scientist. But that's exactly what it would mean if the multiverse theory were correct.

It's an idea that has long fascinated authors and filmmakers. But while it may seem to be little more than a fanciful science fiction trope to most, many prominent physicists take the theory very seriously. Now, researchers from Durham University may have found evidence of the multiverse's existence.

It all comes down the so-called 'Cold Spot' found in the cosmic microwave background (CMB) - the traces of electromagnetic radiation left over from the early stages of the Universe following the Big Bang. The Cold Spot is the largest known structure ever discovered, covering an area billions of light years across. It is around 0.00015 degrees colder than the area that surrounds it. There are other cold regions in the Universe caused by random fluctuations in the CMB but none as large as the Cold Spot - a fact that has puzzled cosmologists since its discovery several years ago.



ABOVE: An artist's impression of multiple 'bubble universes'

The leading theory was that the Cold Spot is not cold at all, but is instead caused by a vast area of relatively empty space dubbed a 'supervoid'. Radiation passing through this void would have its energy reduced, thus making the area appear cooler.

However, new measurements suggest that there is no such supervoid in the direction of the Cold Spot. Assuming this is correct, then simulations of the standard model of the Universe give odds of just 1 in 50 that the Cold Spot arose by random fluctuations.

"This means we can't entirely rule out that the Cold Spot is caused by an unlikely fluctuation explained by the standard model," said lead researcher Tom Shanks. "But if that isn't the answer, then there are more exotic explanations. Perhaps the most exciting of these is that the Cold Spot was caused by a collision between our Universe and another bubble universe. If further analysis of CMB data proves this to be the case, then the Cold Spot might be taken as the first evidence for the multiverse – and billions of other universes may exist like our own."

The team now plan to further test their theory through more detailed observations of the CMB.

"BILLIONS
OF OTHER
UNIVERSES
MAY EXIST LIKE
OUR OWN"

EXPERT COMMENT

What is a bubble universe?

accepted by most, but not all, leading cosmologists – the Universe expanded incredibly rapidly in all directions in a tiny fraction of a second following the Big Bang, much like a balloon does as it is blown up. After this initial quick burst, it continued to expand, but much more slowly.

In contrast, the theory of eternal inflation states that following the Big Bang, inflation did cease in some pockets of space, but also continued in others. This means that we could live in a so-called 'bubble universe' – an area of slowly expanding space embedded in a much larger, rapidly expanding space that is still undergoing inflation.

What's more, there might also be countless other bubble universes embedded in this larger space that are being propelled away from us at breakneck speed. In some of these bubbles, the laws of physics could be completely different from those that apply in our own Universe – making these other universes very strange worlds indeed.

PHOTOS: GETTY X2

MEDICINE

LAB-MADE HUMAN BLOOD IS NOW "TANTALISINGLY CLOSE"

Now here's a bloody good piece of research! A team at Boston Children's Hospital have generated blood-forming stem cells in the lab for the first time, a breakthrough that could enable the development of more effective treatments for genetic blood diseases

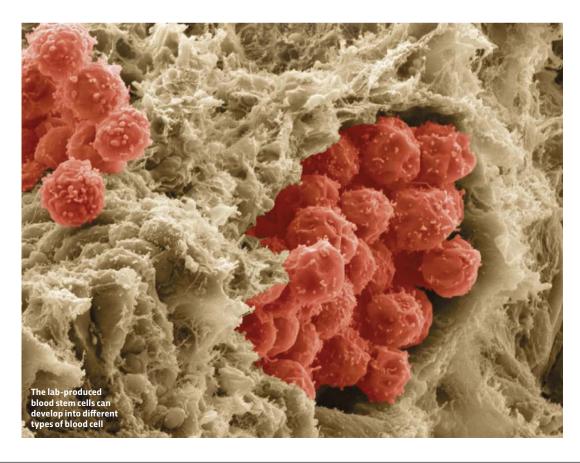
To create the cells, the team used a combination of chemical processes and genetic engineering to coax human pluripotent stem cells – cells capable of forming any adult cell – to differentiate into hemogenic endothelium, an embryonic form of tissue that gives rise to blood stem cells. They then implanted the resulting tissue into mice. Weeks later, a small number of the animals began producing several types of human blood cells. Some mice were even able to mount a human immune response after vaccination.

"We're tantalisingly close to generating *bona* fide human blood stem cells in a dish. This is

the culmination of over 20 years of striving," said researcher George Daley. "We're now able to model human blood function in 'humanised' mice. This is a major step forward for our ability to investigate genetic blood disease."

Although the cells made from the pluripotent stem cells are a mix of true blood stem cells and other cells known as blood progenitor cells, they proved capable of generating multiple types of human blood cells when put into mice.

"This step opens up an opportunity to take cells from patients with genetic blood disorders, use gene editing to correct their genetic defect and make functional blood cells," said researcher Ryohichi Sugimura. "This also gives us the potential to have a limitless supply of blood stem cells and blood by taking cells from universal donors. This could potentially augment the blood supply for patients who need transfusions."



IN NUMBERS

50 DEGREES C

The temperature reached by human mitochondria, the energy factories found in our cells.

100 YEARS

The time the human race has left to colonise another planet to ensure its survival, according to physicist Stephen Hawking.

1.33

x 10²⁹KG

The minimum size a star needs to reach in order to shine, as recently calculated by researchers at the University of Texas at Austin.

RESEARCHERS GOT CRAYFISH TIPSY

How did they do that?

A team at the University of Maryland plunged two groups of social crayfish into a tank spiked with booze. Previously, one group had been housed together in a tank for 10 days, the other group had been kept in solitary conditions. The team observed the animals over three hours to determine how 'drunk' they were.

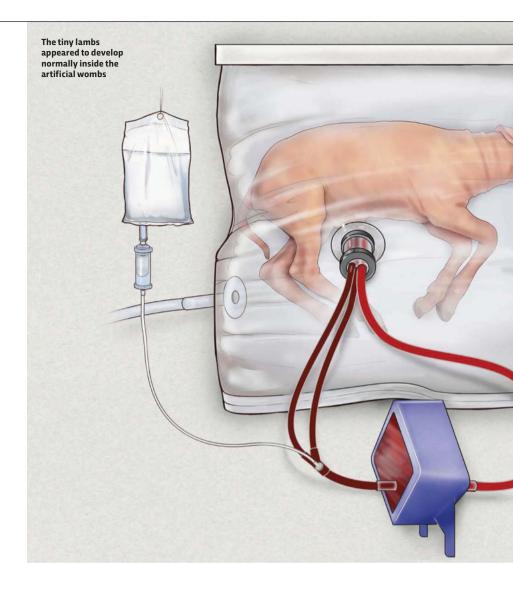
What did they find?

When crayfish are tipsy, they stand more upright and begin thrashing their tails around before finally flopping over onto their backs – a sight eerily similar to the scenes in UK town centres on a Friday night. The team found that it took larger quantities of alcohol to trigger drunken behaviour in the loner crayfish.

Why did they do that?

Though they are keen to stress the fact that the research is still in the preliminary stages, the researchers say that socially isolated humans could show a similar increased tolerance to the effects of alcohol. This could help to explain why those who spend a lot of time on their own often drink more heavily.





BIOLOGY

PREMATURE LAMBS LIVE IN 'PLASTIC BAG' WOMBS

Talk about a womb with a view... researchers at the Children's Hospital of Philadelphia in the US have created a plastic bag-like artificial womb and successfully used it to incubate premature baby lambs for up to 28 days. That's a huge improvement on the maximum 60 hours achieved in previous attempts to develop artificial wombs.

Extreme prematurity (where a baby is born less than 26 weeks into a pregnancy) accounts for one-third of infant deaths in humans.
Currently, premature babies are placed in incubators, and put on

ventilators to help them breathe. But this can lead to lung problems later in life, and the development of other organs is often impaired.

In contrast, the 'biobag' system developed in Philadelphia is designed to more closely mimic conditions inside the mother's womb. The infant's lungs 'breathe' amniotic fluid, just as in a real womb, and their hearts pump blood through an artificial umbilical cord into an external oxygenator. This oxygenator is a substitute for the mother's placenta in exchanging oxygen and carbon dioxide.

PHOTOS: CHILDRENS HOSPITAL OF PHILADELPHIA, SALK INSTITUTE ILLUSTRATION: DANIEL BRIGHT



HEALTH

THE BENEFITS OF EXERCISE: NOW IN PILL FORM

We're all told to exercise more, but for those with physical disabilities that isn't always possible. For such people, the benefits of aerobic exercise have always been out of reach. But now a team at the Salk Institute for Biological Studies in San Diego, California has developed a pill that engenders such effects chemically, with mice given the drug able to burn fat more effectively while exhibiting increased stamina.

When people exercise regularly, their bodies become more adept at using fat rather than glucose as an energy source. It's been known for some time that this ability is linked to the expression of a gene called PPARD – mice that were genetically engineered to have this gene permanently activated proved more resistant to weight gain than normal mice, and had more stamina.

The new research involved giving mice a chemical compound called

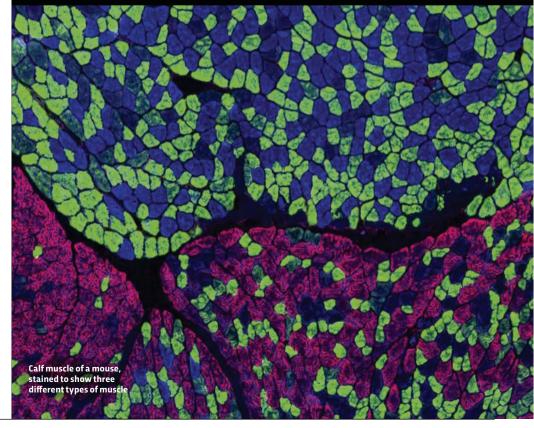
GW1516, which also activates the PPARD gene, over a period of eight weeks. Mice given GW1516 could typically run for 270 minutes before becoming exhausted, compared to 160 minutes for the control group. Closer examination showed that when the PPARD pathway is activated, the expression of 975 different genes within the muscles is affected, with those involved in burning fat increased and those involved in breaking down glucose suppressed.

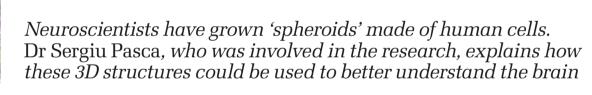
"PPARD is suppressing all the points involved in sugar metabolism in the muscle, so glucose can be redirected to the brain," explained researcher Dr Michael Downes. "Exercise activates PPARD, but we're showing that you can do the same thing without mechanical training."

The research sheds new light on the factors affecting endurance, and offers disabled patients the hope of improved quality of life.

Nutrients are supplied via the umbilical cord, while the bag protects the foetus from changes in temperature and light, as well as keeping germs at bay.

"[Extremely premature] infants have an urgent need for a bridge between the mother's womb and the outside world," said research lead Dr Alan W Flake. "If we can develop an extra-uterine system to support growth and organ maturation for only a few weeks, we can dramatically improve outcomes for extremely premature babies."





ABOVE: Transferred to plates where they cannot attach, stem cells form sphere- like structures

Where do the cells come from?

The ability to transform skin cells into 'induced pluripotent stem cells' has been a revolutionary step and holds great promise for understanding psychiatric disorders. These stem cells can become anything. You can now take a simple skin biopsy and grow cells in a non-invasive way to become cell types of interest.

But there are limitations to what you can do with neurones derived through conventional methods, which involves growing a single layer of cells at the bottom of a Petri dish. One is that the cells don't interact in the same way as they would in the brain. So we've been building three-dimensional spheroid cultures. People have been calling these cultures 'mini-brains', which isn't accurate. It resembles parts, but not the entire human brain.

How do you make a 'spheroid'?

We move stem cells to plates where they cannot attach, so they curl and start making balls. We call them 'spheroids' because they're sphere-like structures. With minimal instructions you can guide the cells to become derivatives of the ectoderm [embryonic tissue that develops into skin and nervous system]. There are all the cell types

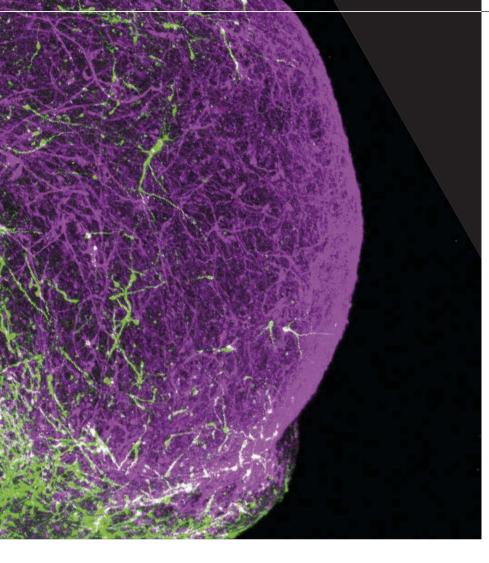
that make the cerebral cortex, which is the outer layer of the brain that's responsible for thinking and most higher brain functions.

Which cells have you studied?

The cerebral cortex has two types of neurones. It has neurones that release glutamate at a synapse (a connection with another neurone) – that excite the other neurone. About 80 per cent of neurones in the cortex are 'excitatory' or 'glutamatergic'. We also have the 20 per cent of neurones we call 'inhibitory' or 'GABAergic' because they release GABA, another neurotransmitter, that puts a brake on the activity of cells. There's a balance between the two types: if you have too much excitation, the consequence is epilepsy and seizures.

What have you found so far?

GABAergic cells aren't made at the same time and in the same place as glutamatergic cells, but in deep structures, migrating over many months to reach the cerebral cortex. So in one dish we make the glutamatergic cells and in another we generate GABAergic cells. After two to three months of maturing, we put them in one tube, label the cells fluorescently and watch them. What happens is



really wonderful: the two spheres fuse. Within weeks they start making connections. We listened to electrical activity and showed they're receiving input from cells around them. So we started recreating a complex neural network, a circuit-like structure that has both cell types, as in the cerebral cortex.

BELOW: Dr Sergiu Pasca has been creating spheroids to ask questions about how different brain cells talk to each other

Why are spheroids useful?

We call this a modular system: you can make specific brain regions and put them together.

This is ultimately a platform that would allow scientists to ask questions about how different brain cells talk to each other, both in isolation as well as when you assemble them in a dish. We can gain insight into what goes wrong, presumably, in the brains of patients with neurodevelopmental disorders such as autism, schizophrenia or epilepsy, which are still untreatable.





HONEST JOHNS

It seems honesty really is the best policy. A team at University College London has found that when we act in a truthful manner our brains find it more satisfying, because a region called the striatum becomes highly activated.

THE FOUL-MOUTHED

Swearing can help to increase our strength and stamina. The effect is thought to be due the stimulating effect foul language has on the sympathetic nervous system. @%#\$!

GOOD MONTH

BAD MONTH

STRADIVARIUS OWNERS

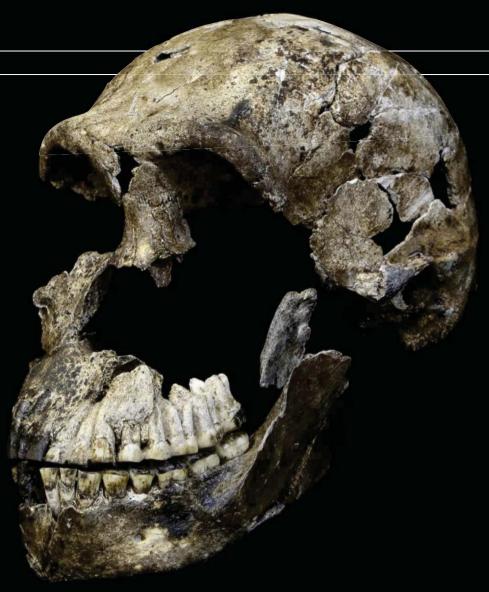
Thinking about dropping millions on a Stradivarius violin? You might want to keep your money in your pocket: a study at Pierre and Marie Curie University, Paris has found modern listeners prefer the sound of new, much cheaper violins.

CHEESE LOVERS

Edam it! Eating cheese made from raw milk could fuel the rise of superbugs. An antibiotic resistant gene found in bacteria from dairy cows could cause difficult-to-treat infections similar to MRSA in humans, researchers at the University of Bern have found.







Neo is the most complete specimen of *H. naledi* that has vet been discovered

ANTHROPOLOGY

ALMOST COMPLETE SKULL OF ANCIENT HOMININ UNEARTHED

In 2015, a team from Witwatersrand University in South Africa announced their discovery of a previously unknown species of early hominin, dubbed *Homo naledi*. The creature, which walked upright and stood 1.5m tall, would have co-existed alongside *Homo sapiens* and *Homo neanderthalis* – modern humans and Neanderthals – around a quarter of a million years ago.

The team's findings were based on fossils that were discovered in 2013 in the Rising Star cave system, near Krugersdorp in Greater Johannesburg. Those original *H. naledi* fossils were found in the caves' Dinaledi Chamber, and consisted of the partial remains of up to 15 individuals. Now, further exploration of the nearby Lesedi Chamber has unearthed over 130 further *H. naledi* fossils, which are believed to have come from just three individuals.

Of these, one adult specimen is remarkably complete and has been given the nickname 'Neo'. This is the word for 'gift' in Sesotho, which is a language spoken in South Africa. Witwatersrand University's Peter Schmid, who has spent hundreds of hours piecing together skull fragments from this individual, said when announcing the news: "We finally get a look at the face of *Homo naledi*."

As well giving us a more detailed picture of the species' physical make-up, the new fossils may shed light on the birth of human cultural traditions. The fact that both caches of fossils were found so far into the cave network has led to speculation that this may be evidence of *Homo naledi* 'burying' their dead in caves. If this is true, it would be one of the oldest examples of such a practice yet discovered.

ASTRONOMY

ASTRONOMERS PIECE TOGETHER STUNNING IMAGE OF THE CRAB NEBULA



Thousands of years ago, thousands of light-years from Earth in the Perseus Arm of the Milky Way, a supergiant star exploded in spectacular fashion. The explosion was so violent that when the light from it reached Earth in 1054, it outshone all the stars and planets in the sky.

In the 19th Century, following the invention of the telescope, the remnants of the event were identified by Anglo-Irish astronomer William Parsons. It became known as the Crab Nebula thanks to the unusual shape of the sketch Parsons made of it. Now, using data from five different telescopes, astronomers have produced an image that shows the nebula in spectacular, unprecedented detail.

The image is a composite of data that spans almost the entire electromagnetic spectrum,

from radio waves detected by the Karl G Jansky Very Large Array (VLA) to X-rays as seen by the orbiting Chandra X-ray Observatory, with infrared from the Spitzer Space Telescope, visible light courtesy of the Hubble Space Telescope and ultraviolet from ESA's X-ray Multi-Mirror Mission (also known as XMM-Newton) in-between. It is hoped that analysis of all this different data will help astronomers gain new insights into the complex physics of the nebula.

"Comparing these new images, made at different wavelengths, is providing us with a wealth of new detail about the Crab Nebula," said astronomer Gloria Dubner. "Though the Crab has been studied extensively for years, we still have much to learn about it."

THE DOWNLOAD

Vaquita

What's that? A tequilabased cocktail? Yummy!

Don't be ridiculous. The vaquita is a species of porpoise that's found in the clear blue waters of the Gulf of California.

So what's so special about it?

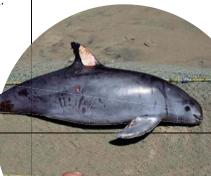
At 1.5m in length, vaquitas are the smallest species of cetacean in the world.
They are often referred to as the 'panda of the sea' thanks to their distinctive black and white markings.

Cute. Anything else?

I'm afraid so. With an estimated 30 individuals remaining, the vaquita is thought to be the world's most endangered marine mammal. Some experts believe that, without drastic action, they could be extinct by 2018.

That's terrible. How come there are so few left?

Vaquita are often caught in gill nets: fishing nets that are hung vertically so that fish get snagged by their gills. The problem is exacerbated by the illegal demand for the bladder of the totoaba – another critically endangered species that is native to the region – for use in traditional medicine.





PALAEONTOLOGY

INCREDIBLY WELL-PRESERVED DINOSAUR FOSSIL PIECED TOGETHER

It may resemble the sort of creepy statue that would look at home in a supervillain's hidden lair, but this intimidating beastie is in fact the 112-million-year-old fossil of a nodosaur.

Nodosaurs were herbivores whose bodies were encased in tank-like armour and spikes to protect them from predators. This particular example is 5.5m in length and weighs over 1,000kg. The fossil is currently on display at the Royal Tyrrell Museum of Palaeontology in Alberta, Canada, but was originally discovered in the nearby Suncor Millennium Mine in 2011, by a Suncor employee who was excavating in the mine.

The fossil was then moved to the museum.

"THE
NODOSAUR
SKELETON
MEASURES 5.5M
IN LENGTH AND
WEIGHS OVER
1,000KG"

where its bones were painstakingly cleaned and pieced together – a process that took some 7,000 hours to finish. Now complete, it is one of the best-preserved dinosaur fossils in the world, showing the animal's anatomy in incredible detail.

The reason for its almost unprecedented state of preservation, researchers say, is its manner of death. It's likely that the dinosaur fell into a river and was swept out to sea by strong currents or a flood, where it sank to the seabed. Over the course of millions of years on the ocean floor, minerals took the place of its skin, forming an eerily life-like fossil.

BIOENGINEERING

3D-PRINTED OVARIES LET MICE GIVE BIRTH TO **HEALTHY PUPS**

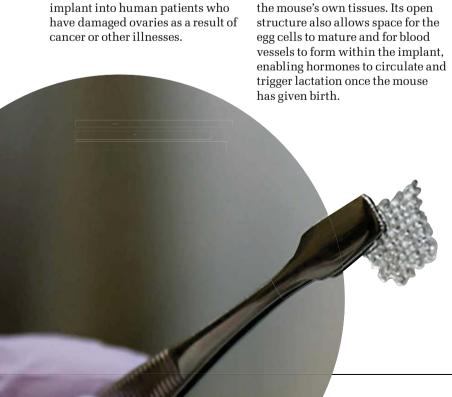
Infertile women wanting to have children have been offered fresh hope, after scientists at Chicago's Northwestern University have successfully 3D-printed fully functioning mouse ovaries.

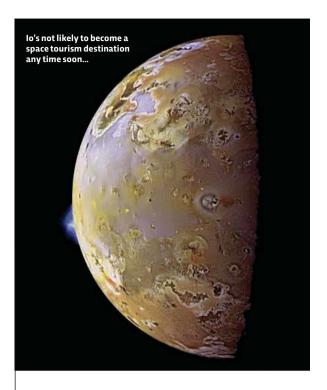
In a world first, the team implanted the artificial ovaries into mice, which were then able to produce eggs, mate and give birth to healthy pups. They were even able to nurse their young naturally after they were born.

The technique has so far only been tested in animals, but the ultimate goal of the research is to produce artificial organs to

"This research shows these bioprosthetic ovaries have longterm, durable function," said researcher Teresa K Woodruff. "Using bioengineering, instead of transplanting from a cadaver, to create organ structures that function and restore the health of that tissue for that person, is the holy grail of bioengineering for regenerative medicine."

The ovaries were built on 3D-printed gelatin scaffolds that were then populated with immature eggs. Gelatin is rigid enough to handle during surgery but porous enough to interact with





HUGE WAVES OF LAVA SPOTTED ON JUPITER'S MOON

Anyone travelling to Jupiter's moon Io might find themselves in an environment resembling hell. Io is the most volcanically active body in the Solar System, with a landscape peppered with hundreds of smoking volcanoes and vast, lava-filled lakes.

Working at the Large Binocular Telescope Observatory in southeast Arizona, researchers from the University of California have observed huge waves flowing through the largest of these lakes, Loki Patera. They measured the infrared radiation emanating from Io in March 2015 when another of Jupiter's moons, Europa, passed in front of it. As Europa's surface is covered in ice, it reflects very little sunlight at infrared wavelengths. This gave the researchers a rare opportunity to isolate the heat emanating from volcanoes on Io's surface.

The infrared data showed that Loki Patera's surface temperature steadily increased from one end to the other, suggesting that the lava had overturned in two waves that each swept from west to east at about a kilometre per day.

"If Loki Patera is a sea of lava, it encompasses an area more than a million times that of a typical lava lake on Earth," said researcher Katherine de Kleer. "In this scenario, portions of cool crust sink, exposing the incandescent magma underneath and causing a brightening in the infrared."

EATING BOGIES IS GOOD FOR YOU

According to research at Harvard University, nasal mucus is full of friendly bacteria that can boost your immune system when consumed. Ew.

FACE-TO-FACE REQUESTS ARE 34 TIMES FOR SUCCESSFUL THAN EMAIL ONES

If you want something doing, request it in person, say psychologists at the University of Western Ontario. The effect is thought to be due to the non-verbal clues conveyed when speaking face-to-face.

BEAUTY SLEEP REALLY DOES EXIST

The sleep-deprived are deemed to be less attractive and less healthy than the well rested, a team at Stockholm University has found.

HARDLY ANYBODY WILL OWN THEIR OWN CAR IN 2030

The advent of self-driving electric vehicles will see privately owned cars making up just 5 per cent of all traffic, a team at California think tank RethinkX has estimated.



IMAGING

FUNERAL EFFIGIES OF NELSON AND PITT THE ELDER SCANNED IN MINUTE DETAIL

Here's something to wax lyrical about: a team at King's College London has 3D scanned the funeral effigies of British naval hero Lord Horatio Nelson and 18th-Century prime minister William Pitt the Elder, using a cutting-edge CT scanner at St Thomas' Hospital.

The waxwork heads were being investigated as part of a collaboration with Westminster Abbey. The team hopes to discover more about the structure and composition of the heads, which are currently undergoing conservation before going back on display.

"Our high-tech scanner is used on a daily basis to diagnose and monitor patients, so it was a very different experience to use it to examine wax effigies which are hundreds of years old," said Ronak Rajani, consultant cardiologist at St Thomas'. "We hope that the findings from the scans can shed light on how these unique wax works were made."

The Abbey has a large collection of funeral effigies, dating back hundreds of years. They were originally made to sit on top of the deceased's coffin, dressed in ceremonial clothes, in memory of the person lying inside. Nelson's wax head was made during his lifetime and acquired by the Abbey as a tourist attraction after his death, while the wax head of William Pitt is the last known surviving effigy made by famous 18th-Century US wax sculptor Patience Wright.

The two effigies will form part of the display in a new gallery at Westminster Abbey next year.

PHOTO: GETTY



THE CHOLESTEROL DRUG CONTROVERSY

The debate about statins shows that science can't always supply easy answers

In these days of fake news and 'alternative facts', science gives us the tools to blast through the bluster. But even the scientific method can struggle to cut through really tough stuff.

Take the ongoing controversy over statins, the cholesterol-lowering drugs that millions of people take every day to help them avoid heart attacks and strokes. For years, patients have complained of getting muscle pain so severe they've stopped taking their pills. Quite why statins should have this effect isn't clear; what is clear, though, is that while patients believe these pains are real, many medical experts don't.

Now a huge scientific study involving over 10.000 patients has shown that the experts were right: the muscle pains are all in the mind. The evidence comes from a 'double blind' randomised trial, widely recognised as the gold standard research study. The participants were randomly assigned either to receive the treatment or not - with neither they nor the researchers knowing who got what.

When the results were analysed, they showed that around 2 per cent of participants reported muscle pains over the following year regardless of whether they were taking statins or not. But then the researchers looked at what happened once people knew they were taking statins. Complaints of muscle pain suddenly became over 40 per cent more common among those taking the drug.

Reporting their work in the peerreviewed medical journal The Lancet, the researchers explain that this is consistent with the so-called 'nocebo effect' - the evil twin of the betterknown placebo effect - in which simply knowing they are taking an active drug leads people to believe it's having a bad effect on them.

The results made headlines, and prompted calls for patients not to gamble with their lives by wrongly blaming statins for symptoms and ditching them, thus increasing their risk of heart attacks and strokes.

"TELLING **PEOPLE** THEY'RE **JUST FEELING 'ALTERNATIVE** PAIN' ISN'T LIKELY TO **PROVE ALL THAT HELPFUL**"

On the face of it, this is a textbook example of how science can debunk 'alternative facts'. Yet it's not quite as simple as that.

For a start – and as the lead researcher said at the time - just because the pain is caused by the nocebo effect, doesn't mean patients don't feel it. Telling people they're just feeling "alternative pain" isn't likely to prove all that helpful. But there are other issues with the research, too.

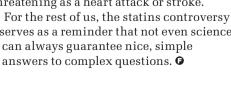
First, the study itself was finished over a decade ago and involved only one type of statin, at a dosage lower than is commonly prescribed today. The participants were all European males - clearly unrepresentative of the population as a whole – and they were not instructed to report any side-effects, raising the possibility that many went unreported. Then there's the awkward fact that the study was funded by drugs companies who make statins. So while the basic study design was scientifically impeccable, the details of how it was carried out leave question marks hanging over its conclusions.

That's also true for the bigger question surrounding statins: who should take them?

While the benefits for patients at high risk of cardiovascular disease are undisputed, medical experts are divided on the merits of giving statins to anyone else. Anyone who thinks 'alternative facts' are the sole preserve of politicians should check out the ongoing spat between The Lancet and the British Medical Journal on all this.

If you're taking statins, you should see your doctor before deciding what to do in the light of all the conflicting messages, but it's worth bearing in mind that while the side effects may be unpleasant, they're not as lifethreatening as a heart attack or stroke.

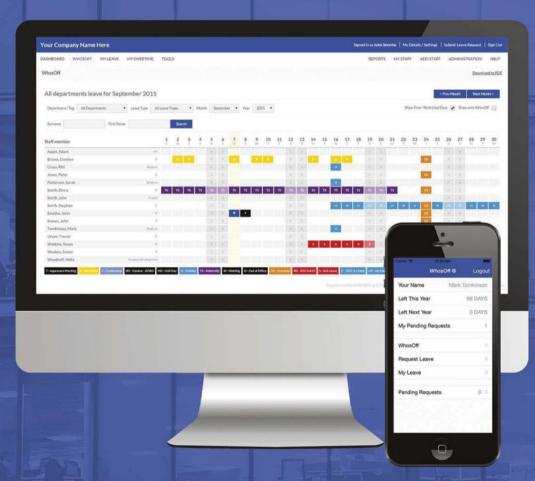
> For the rest of us, the statins controversy serves as a reminder that not even science can always guarantee nice, simple answers to complex questions. 9



Robert Matthews is visiting professor in science at Aston University, Birmingham.

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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

JULY 2017 EDITED BY RUSSELL DEEKS



THE F1 CAR OF THE FUTURE?

LIOTO, NIPVA/CROF.

Seen here is the Renault R.S. 2027 Vision. This futuristic Formula 1 car concept was unveiled at the recent Auto Shanghai trade fair to showcase the technologies the French motoring giant thinks will become dominant in the sport over the next decade or

so. These include hybrid electric/liquid fuel engines, four-wheel drive, a transparent, 3D-printed cockpit, wheels with a built-in LED display, and greatly reduced weight – the R.S 2027 Vision tips the scales at 600kg, over 100kg lighter than current F1 models.









WANTED

TALKING SPEAKERS

For proof that Alexa/Siri-style digital assistants are becoming ubiquitous, see Vizio's latest soundbars, which have Google Assistant built-in but barely bother mentioning it. Built-in Chromecast is what they shout about instead. Vizio SmartCast

\$250-\$500 (£193-£386 approx), vizio.com

SELFIE SERVANT

This tiny quadcopter sports a 5MP camera, weighs just 61g and comes with a charging station that doubles as a smartphone case. It only flies for three minutes, but as it's designed purely for taking selfies, that shouldn't be too much of a problem. AirSelfie

€358 (£300 approx), airselfiecamera.com

DON'T LOOK MAC IN ANGER

This £30 stand turns your iPhone 6/6s/7 into a replica of the original 1984 Apple Macintosh while charging it overnight. For added retro fun, just add the original MacOS, which you can now run in a browser via Archive.org.

M4 Vintage Stand for iPhone €34.95 (£30 approx), www.elagostore.eu

ECHO, ECHO ON THE WALL...

Amazon wants you to put an Alexa-equipped Echo Look in your bedroom, so you can take selfies in your latest gladrags. It can even compare two outfits to tell you which looks best. Just remember to switch it off when you're done...

Amazon Echo Look \$200 (£155 approx), amazon.com SNAP HAPPY

Sony's new flagship 4K camera is a mirrorless, 24.2-megapixel affair with a full-frame stacked CMOS sensor. It'll shoot RAW images at a blistering 20fps, while tracking moving subjects is simple thanks to autofocus with a 60Hz refresh rate. Sony A9

£4,500, sony.com

WE HAVE LIFT-OFF

This Lego model of the Saturn V rocket used for NASA's Apollo missions comprises nearly 2,000 pieces, stands a metre tall and, just like the real thing, can be broken down into its S-IC, S-II and S-IVB sections. We want one.

NASA Apollo Saturn V \$120 (£93 approx), lego.com



ALL-SEEING EYES

This year's must-have for the early adopter contingent is a 360° camera. **Luke Edwards** checks out four of the latest entry-level models

WHAT TO LOOK FOR

- 4K resolution will make your purchase relatively future-proof.
- Good quality video stitching is a must if you want your content to be truly immersive
- Higher frame rates will make for smoother VR footage, and reduce the risk of inducing nausea in viewers.
- The lighter and more portable the better – both for ease-of-use and for not making you feel like a massive dork when you're using it.





INSTA360 NANO

£209, insta360.com

Encased in brushed metal, the Insta360 Nano is designed as an add-on for the iPhone – it's compatible with models 6 and upwards – though it also works as a standalone camera, albeit one with no live preview screen. It's got twin, opposite-facing 210° lenses, shooting 30fps at 3K resolution. The accompanying app is simple to use and makes sharing pictures and videos to YouTube and social media a breeze. Don't chuck away the box – it doubles up as a Google Cardboard-style headset, which is a nice touch. **9/10**

SPECS: 3,040 x 1,520 resolution, f/2.0 lens, TF card storage, 800mAh battery, 33mm thick, 70g.

KODAK PIXPRO SP360 4K DUAL PRO PACK

£699, kodak.com

This precursor to the upcoming Orbit 360 4K uses two cameras. It's a bit fiddly to set up, and the app isn't amazing – you can't upload straight from the camera to YouTube, for instance. Still, the quality of the resulting footage makes up for these niggles, with the stitching of panoramic images particularly impressive. While it's rugged and boasts decent battery life, the Orbit 360 4K will do all this without the two-camera faff, so you may want to hang on for that one. **6/10**

SPECS: 12MP r, f/2.8 lens, 2x 235° lenses, Wi-Fi, NFC, 4K equivalent VR video, 128g





NIKON KEY MISSION 360

£419. nikon.com

Built for action this cam is water, dust and shock proof. The KeyMission also comes with a GoPro-style mount which you can attach to a hand-grip if you want to use it like a camcorder. On a sunny bike ride the footage was crisp, adapting to dappled light well, but at the full 4K-resolution the frame rate became stilted. There's a single-button control on the cam-just press it to film, and the rest of the controls are accessed via the SnapBridge 360 app. This makes the camera easy to use spontaneously, but frustrating when you want to start playing with settings. Footage comes YouTube/Facebook ready. 6/10

SPECS: 23.9MP CMOS sensor, f/2.0 lens, Wi-Fi, 4K equivalent VR video, supports MicroSD cards up to 128GB, 198g



ZUCKERBERG AND MUSK WANT TO READ YOUR MIND

Two giants of the tech world, Facebook and Elon Musk's latest venture Neuralink, have both announced that they are working on brain-to-computer interfaces.

At Facebook's recent F8 developers' conference, Regina Dugan from Facebook's R&D division Building 8 showed a video of a woman using such an interface to type eight words per minute, and spoke of the company's ambitions to develop a similar system capable of typing hundreds of words per minute within a few years. Dugan has experience in this area: the technology in the Stanford University video was similar to systems developed at DARPA, the US military research agency, while Dugan was director there.

Facebook CEO Mark Zuckerberg later enthused about the technology in a Facebook post, saying: "We're working on a system that will let you type straight from your brain about five times faster than you can type on your phone today. Eventually, we want to turn it into a wearable technology that can be manufactured at scale."

Meanwhile at Neuralink, work is in progress on a system to help restore communication to brain injury and stroke victims. Musk says they expect to have a product on the market "in about four years".





SPACE ARMOUR

In its ongoing quest to build better spacecraft, NASA has looked to the distant past for inspiration and invented a form of 21st-Century 'chain mail'.

The new material was invented at NASA's Jet Propulsion Laboratory (JPL) by a team led by Raul Polit Casillas. Its outward-facing side resembles the surface of a mirror ball and reflects light and heat, whereas the inward-facing looks more like actual chain mail and absorbs heat. It's hoped the material could have applications as protective (and insulating) cladding for spacecraft, in astronauts' suits, or even for creating temporary landing strips. What's more, it's 3D-printed, which means it could be produced on-demand in any putative future base stations on Mars or the Moon.



MEDICINE

FINAL FRONTIER WINS TRICORDER XPRIZE

The DxtER from Final Frontier Medical Devices has won the Tricorder XPrize, a \$7m grant to develop an all-purpose medical diagnostic device along the lines of the 'tricorder' used in *Star Trek*.

The Tricorder XPrize competition was launched in January 2012, as a joint venture between the XPrize Foundation (whose directors include Google founder Larry Page and Huffington Post founder Arianna Huffington) and US telecoms giant Qualcomm. And now Final Frontier's device has been chosen as a winner, even though the DxtER isn't actually particularly tricorder-like at all.

Rather than being one single multipurpose device, DxtER consists of several discreet components, including heart rate and respiration monitors, a compact spirometer, and a dual-purpose thermometer and stethoscope called the

DxtER Orb. Plus, the DxtER system has been designed – unlike the *Star Trek* tricorder – for use by patients themselves rather than by medical professionals.

Final Frontier is currently seeking approval from the US Food and Drug Administration (FDA) for its devices. If such approval is granted, treatment times in hospitals could be reduced as there'd be no need for doctors to repeat tests that had already been carried out by the patient at home using DxtER.





TECH BYTES

FACEBOOK IS HIRING

Facebook is taking on an extra 3,000 moderators to monitor video content. The move comes after several high-profile incidents in which murders, suicides and sexual assaults were live-streamed using the Facebook Live service.

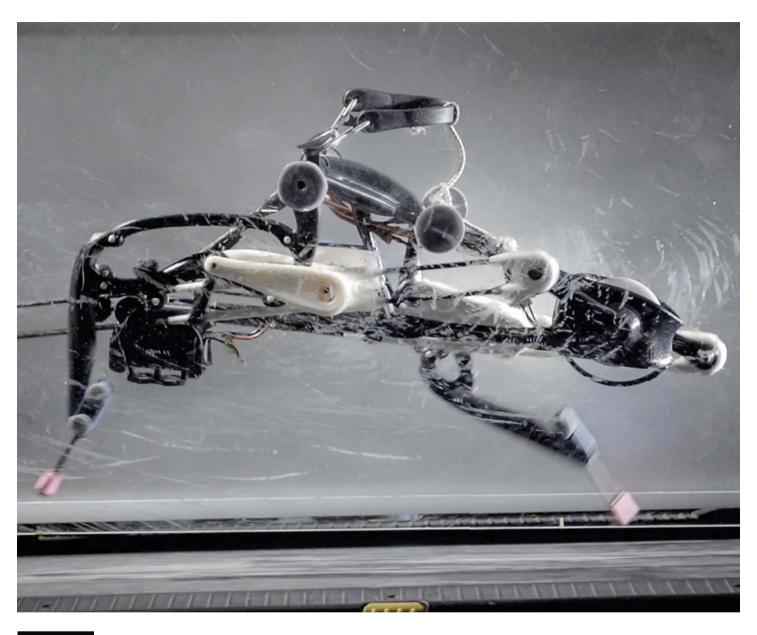


LARGING IT

A team at MIT has created the world's biggest 3D-printed structure (above). The 15.25m x 3.66m igloo-like dome was constructed from quickdrying foam in just 13 hours by a large, hydraulically mounted 3D-printing robot dubbed, imaginatively, the Digital Construction Platform.

FASTEST CAMERA

Researchers at Lund
University in Sweden have
developed a camera that can
shoot an incredible five
trillion images per second.
The camera, which uses lasers
rather than natural light, is
designed for capturing
chemical reactions on film.



ROBOTS

FIRST SELF-BALANCING ROBOT

This robot is the Planar Elliptical Runner (PER). It's the brainchild of Jerry Pratt and his team at the Florida Institute for Human and Machine Cognition (IHMC). What's unusual about the robot is that it doesn't require advanced AI systems to stay upright.

Similar-looking robots from the likes of Boston Dynamics or Agile Technologies rely on gyroscopes, sensors and advanced algorithms to keep them on their feet, but the PER makes use of a simple, stable design with a single motor that drives its legs in an elliptical motion. The robot, whose gait resembles that of an ostrich, can reach a speed of 19km/h (12mph). However, it has been suggested that were the robot scaled up to human size, this could increase to 48km/h (30mph).

While PER is essentially just a proof of concept, it's hoped that the technological and design lessons learned will eventually help in the development of robots that can go to dangerous or inhospitable places, such as burning buildings. Pratt said: "Running will be eventually useful for any application that you want to do quickly and where wheels can't work well."

FOCUS READER SURVEY

Welcome to our reader survey. This is your chance to tell us what you think about BBC Focus magazine, and help shape how it evolves in the future. The more we understand about your hobbies and interests, likes and dislikes, the more relevant and enjoyable we can make BBC Focus magazine for you. Please return your completed questionnaire to the Freepost address supplied at the end by 28 June 2017, or alternatively you can fill it in online at sciencefocus.com/readersurvey. UK residents who return a completed questionnaire have the opportunity to enter our prize draw for a chance to win one of five £100 Amazon vouchers; please see our T&Cs on p38 for more information. We look forward to hearing from you!



As a source of general knowledge

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Always – I subscribe	□ 1	I like the digital only content	05 Going to a science/tech museum/exhibition
Always – I don't subscribe, but I buy every issue Quite often – once every 2-3 issues	□ 2 □ 3		06 Going on a science-related holiday 07 (eg, to see the Northern Lights)
Occasionally – once every 4-13 issues	□4	Other (please specify)	
This is my first issue	□ 5		National Park or conservation area)
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BBC Wildlife magazine		Science-related TV shows (eg, Horizon)	and as many secondary reasons as apply.
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	1 2 3	Male	□ 1	county of residence may be released if they win a prize; and (
		Female	□ 2	they win the promotion, their name and likeness may be used for pre-arranged promotional purposes. Entrants should ente
Technology				the survey. Completed surveys received after the closing date
Gadgets		30. Which age group are you in?		will not be considered. Only one entry will be permitted per pe
Engineering				entries made by third parties will not be permitted. The winnir drawn at random from all the completed survey entries after t
Military		Under 16*	□ 1	The Promoter's decision as to the winners is final and no corr
Psychology		16-24	□2	relating to the promotion will be entered. The winners will be r
Medicine		25-34	□3	days of the close of the promotion by email or phone. There w prize winners, each winning 1x £100 Amazon voucher. There
Health		35-44	□ 3 □ 4	alternatives, vouchers or refunds available. The prize is non-t
			□ 4	non-refundable and subject to availability. The Promoter rese
Genetics Space exploration		45-54 FF 64		substitute the prize with one of the same or greater value. The
Space exploration		55-64 65 ·	□ 6	county of residence of the winners will be available by sendin BBC Focus Magazine Reader Survey, Immediate Media Co,
Maths		65+	□ 7	Fairfax St, Bristol, BS1 3BN within two months of the closing
Artificial Intelligence		*Unfortunately the prize draw is only open to adults aged 16+		promotion. The Promoter reserves the right to amend these to
Cosmology				conditions or to cancel, alter or amend the promotion at any s necessary in its opinion, or if circumstances arise outside of i
Physics		31. What is your current employment status?		Promoter does not accept any responsibility for lost, delayed
Chemistry				entries. If any winner is unable to be contacted within 28 days
Our future		Employed full-time	□ 1	promotion's closing date, the Promoter reserves the right to o
Nature		Employed part-time	□2	runner-up, or to re-offer the prize in any future promotion. The excludes liability to the full extent permitted by law for any los
Environment		Studying full-time	□3	injury occurring to the participant arising from his or her entry
Robotics		Studying part-time	□ 4	promotion, or occurring to the winner arising from his or her a
Anthropology		Retired	□ 5	prize. The promotion is subject to the laws of England. The Pr
Current affairs		Not working	□6	entrants' personal details in accordance with the Immediate F (www.immediatemedia.co.uk/privacy-policy).
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High managerial, administrative or professional Intermediate managerial, administrative or professional Supervisory, clerical and junior managerial, administrative or professional Skilled manual Semi-skilled or unskilled manual Unemployed Student	□ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7
33. What is your household income before tax?	
Under £20,000 £20,000-£29,999 £30,000-£39,999 £40,000-£49,999 £70,000-£99,999 £70,000-£99,999 £100,000-£150,000 Prefer not to say	□ 01 □ 02 □ 03 □ 04 □ 05 □ 06 □ 07 □ 08 □ 09
34. Is your home	
Mortgaged Owned outright Rented Other	□ 1 □ 2 □ 3 □ 4

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MESSAGE OF THE MONTH

Urine trouble

I was most disappointed to read, in your otherwise excellent magazine, that you chose to report the fake news masquerading as a 'statistic' regarding urine released in a swimming pool (May, p82).

Surely that statistic is unverifiable and would actually require most of us (we!) swimmers to be incontinent? I suspect the 'news' was released to the media by a pathological non-swimmer who has had to endure taking his kids to early morning swimming lessons!

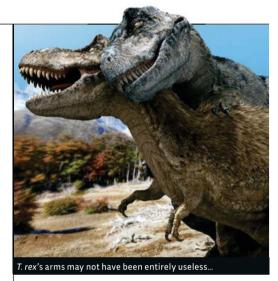
Conversely, and perhaps more worthy of your attention, all swimming pools are checked daily, by water sample, for faecal contamination (not for urine) and therefore it should be possible to work out exactly how much poo is floating about in the average swimming pool in a day. An ideal project for that intern, surely?

Keep up the good work, I find the articles on particle physics most enjoyable. Richard Graham, Aberdeenshire

Sorry to be the bearer of bad news, but the statistic - that 75 litres of urine was 'released' in a large pool over a three-week period - came from a study published in the journal Environmental Science & Technology Letters. They tested a public pool for traces of artificial sweeteners, as these aren't metabolised by the body as they pass through. - Ed

WRITE IN AND WIN!

The writer of next issue's Message Of The Month wins an iHealth Lite Wireless Scale. This glass bathroom scale sends information about your weight and body mass index (BMI) to the free iHealth MyVitals app on your smartphone, enabling you to track your weight over time, while its backlit display auto-adjusts its brightness to suit the light in the room. telmenow.com



Hang on a minute...

Regarding the always fascinating T. rex's forearms. To me, it seems likely they were needed for mating activities - the need for stable contact here seems obvious! Also, the arms would have been useful for mud nest building, as well as egg and baby handling. Who knows, maybe even the odd hug - he might have been a real family guy. Max Jones, via email

Relatively interesting

Re: 'The universal fabric' (April, p64) what an amazing article! Jeff and Brian are to be congratulated. The writing really got my brain spinning, and I have a question. If a piece of radioactive material were travelling towards Earth at a high portion of the speed of light, would observers on Earth see the rate of decay slow down? Phil Grantfriesen, via email

Yes. This effect is really pronounced for cosmic ray particles called muons. They are made in the upper atmosphere and then stream down to Earth's surface. At rest, muons have a lifetime of just two microseconds; if they had the same lifetime when travelling down to the Earth, they'd never hit the ground. Instead, they live for much longer according to Earth-bound clocks, and as a result they do reach the surface. - Jeff Forshaw

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WHAT'S THE BEST DIET FOR THE PLANET?

The neverending deluge of information about our food choices can be baffling. So should we all become vegan, or can we really have our steak and eat it?

WORDS: JOSH GABBATISS



iet can be a contentious issue, subject to the forces of personal ethics, religious beliefs and health concerns. But when it comes to the environment, for many people it's an

open-and-shut case. "The evidence is all there, you just need to look for it," my vegan friend told me recently, with the kind of sanctimonious air that puts some people off veganism altogether.

The thing is, although I'm not a vegan myself, I suspect he's probably right. While I'm quite sure this is not the stated aim of most vegans, abstaining from animal products does seem to give you the moral high ground in the environmental stakes. I've watched *Cowspiracy*, I know the deal. At the same time, I'll admit to being a little put off by how self-assured some people seem in their dietary choices. Seldom does all the evidence point in one direction, and when considering something as multifaceted as the global food system, perhaps it's unwise to generalise.

In recent years, scientists and the public have become increasingly aware that the food we eat can have negative impacts on the planet. With this in mind, it's worth asking – whichever side of the fence you're on – whether the evidence really is 'all there', and whether there exists a diet that is objectively best for the environment.

This is not a straightforward issue. According to figures from the Consultative Group on International Agricultural Research (CGIAR), one-third of our greenhouse gas emissions come from agriculture. But that's just one factor. Our food system is also the leading cause of deforestation, land use change and biodiversity loss in the world. Then there's overfishing, pollution, groundwater depletion, excessive fertiliser use and pesticides to contend with as well. With all these issues to consider, a 'sustainable' diet might mean different things depending on who you talk to. However, certain trends cut through the noise — most notably, an emphasis on more plant-based diets. lacksquare

▶ The idea that vegetarianism is good for the planet is relatively new. Back in 1971, a visionary book by Frances Moore Lappé entitled *Diet For A Small Planet* suggested that world hunger could be remediated if less emphasis was placed on meat in Western diets. Her recipes for spinach lasagne and soy burgers caused a stir at the time, but skip forward 46 years and official guidelines everywhere from the Netherlands to the US emphasise lower meat consumption for a healthy body and a healthy planet. Vegetarianism has gone mainstream. In a report from the US-based 2015 Dietary Guidelines Advisory Committee, the

"WHILE PLANT-BASED DIETS HAVE NOW BEEN NORMALISED, VEGETARIANS AND VEGANS ARE STILL RELATIVELY THIN ON THE GROUND"

authors concluded:
"Consistent evidence
indicates that, in general, a
dietary pattern that is
higher in plant-based foods
... and lower in animalbased foods is more health
promoting and is associated
with lesser environmental
impact than is the current
average US diet."

These are not empty words. Study after study has demonstrated the beneficial effects of a plant-based diet for the environment. A paper published last year in Proceedings Of The National Academy Of Sciences concluded that a mass switch to vegetarianism would bring

down food-related greenhouse gas emissions by a whopping 63 per cent, while even just sticking to global health guidelines regarding meat consumption (so laying off the burgers a bit) would be enough to reduce emissions by 29 per cent.

As for veganism, it does seem to be edging ahead in the planet-saving stakes. Many of the issues that arise from farming livestock for meat – methane emissions from animal digestion, pollution from farms, energy-intensive feeds – also apply to the dairy and egg industries. If widespread veganism was enacted, that 63 per cent reduction in emissions shoots up to 70 per cent.

IN DEFENCE OF CARNIVORES

These seem like hard figures to ignore, and yet ignored they are by the vast majority of people. While plant-based diets have now been normalised in a way that was probably unimaginable in Lappé's day, practising vegetarians and vegans are still relatively thin on the ground. It's thought only 2 per cent of the UK population is vegetarian, and less than 1 per cent is vegan.



But stop the press! Maybe cutting out animal products entirely, or even nearly entirely, isn't necessarily the way to go. There have been studies published in reputable journals which suggest that vegetables may not be our sole salvation. Back in 2015, a particular paper caused a media firestorm when its lead author, Prof Paul Fischbeck of Carnegie Mellon University, made the declaration that "eating lettuce is over three times worse in greenhouse gas emissions than eating bacon". "LETTUCE WORSE THAN BACON" screamed the headlines, as commentators smugly observed that vegetarianism isn't all it's cracked up to be.

Other research has suggested that at least some degree of carnivory could be beneficial. A recent analysis of 10 distinct diets, each with a different ratio of meat and animal products, saw veganism relegated to fifth position when it came to maximising sustainable land use, below different



degrees of vegetarianism and omnivory. This comes as a blow to vegans who tend to assume, understandably, that due to the well-documented problems with livestock farming, their diet plan automatically places them in the top spot.

THE DEVIL IN THE DETAIL

How can researchers come to such different conclusions? Well, the short answer is because they're trying to answer a complicated question. To work out the best diet for the planet, scientists tally up the environmental costs of the production, transportation and marketing of foods, and then compare the options. Yet there are many such costs involved, and therefore many potential metrics. Some researchers completely ignore certain aspects, such as the amount of food that is wasted, while others place more emphasis on aspects that they deem to be most relevant. lacksquare

ABOVE: Shelves groan with food at a Tesco distribution plant in Reading, UK

RIGHT: Modern Western diets still contain too much meat



● For example, there is no question that red meat produces far more emissions than vegetable protein sources like lentils and beans – around 13 times more, in fact. But if you're focusing on land use, then cows and sheep start to make a lot of sense. Livestock, and food for livestock, can be farmed on land that's unsuitable for human crops, so if that land can be put to good use it will improve the efficiency of food production in a given area.

As for the idea that lettuce is worse for the environment than bacon, the researchers had opted to analyse emissions on a per calorie basis. This seems an unfair comparison. After all, no one is suggesting that vegetarians replace two rashers of bacon at breakfast with the 3.3kg of lettuce it would take to match them, calorie-wise. But what Fischbeck and his colleagues wanted to emphasise was the need to consider foods on their individual merit, rather than assuming that just because you have chosen diet A or diet B, you are automatically saving the world.

VARIETY IS THE SPICE OF LIFE

This is a good point. There is an awful lot of variety in green credentials, even within food groups. Beef and lamb produce far more emissions than pork, which in turn produces more than chicken. As for BELOW: Recently, 'dumpster divers' have put food waste in the spotlight by salvaging edible food from skips fish, the variation in impact is enormous, so diverse are the means by which different species are caught or farmed and the levels of threat they are all under in different parts of the world.

Fruits and vegetables are even more complicated. Robust produce that can be grown in fields, such as cabbage and potatoes, result in



SAVING THE WORLD, ONE BITE AT A TIME

5 THINGS TO EAT MORE OF:



MUSSELS These shellfish can be grown on ropes, causing minimal damage to the marine ecosystem. But they can also absorb carbon from the environment to grow their shells. What's more, being filter feeders they require no feed input whatsoever. They're full of fatty acids and vitamins too.



LEGUMES
Compared to other
protein sources,
legumes – beans, peas
and lentils – require
little water or fertiliser,
and their carbon
footprint is low. These
plants even 'fix'
nitrogen from the
atmosphere into the
soil, converting it into
ammonia that other
plants need to grow.



TILAPIA
These freshwater fish
can be grown in closed
tank systems, avoiding
the water pollution
usually associated
with fish farms. As they
are not carnivores like
many commercial fish
species, they don't need
to be fed fishmeal,
which means their diet
doesn't deplete wild
fish stocks.



SOFT CHEESE
Cheese generates the
most greenhouse gases
after red meat, which is
something that
non-vegan vegetarians
ought to bear in mind.
However, if you must eat
it, opt for the softer
varieties as they
contain less milk, and
tend to require less
energy during the
production phase.



LOCAL, SEASONAL FRUIT AND VEGETABLES
Yes it can be somewhat limiting, but around 10 per cent of any food item's greenhouse gas emissions comes from its 'food miles'. You can limit those emissions if you buy produce that was grown across the street, not across the ocean.

relatively low greenhouse gas production, but if a plant requires intense refrigeration, or has to be grown in a hot house, alarm bells begin to ring. Similarly, vegetables which must be flown great distances before they arrive on your plate come with a sizeable emissions price tag. That's before you even consider the huge quantities of water needed to grow citrus fruits, or the pesticides that are pumped into banana plantations. Greenhouse gases, though the most widely used measure of impact, only tell one side of a far more complicated story, and those who opt for more plant-based diets must be wary of replacing the animal parts of their diet with plants that cause harm in other ways.

The fact is, whichever label you choose to define yourself – vegan, vegetarian, pescetarian or omnivore – there's no room for complacency. Ultimately, the choices you make about your food are just as important as the diet tribe you belong to.

FUTURE FARMING

Another layer of complexity is the variety of farming strategies in use. Rather than demonising meat, some argue, policies could ensure that livestock farming is more efficient and produces fewer greenhouse gases. This may sound a little too good to be true, but scientists have suggested that by simply supplementing the grazing diets of cattle

"ULTIMATELY,
THE CHOICES YOU
MAKE ABOUT
YOUR FOOD
ARE JUST AS
IMPORTANT AS
THE DIET TRIBE
YOU BELONG TO"

and sheep with higher quality feeds, emissions from livestock farming could be reduced by nearly a quarter in the next two decades.

So relatively simple changes can make a difference, but when considering the scale of our food system's impact on the planet, something bigger might be necessary. Industrial agriculture has been our go-to system for some time, but the overuse of powerful chemical pesticides and fertilisers is resulting in degraded ecosystems that are

ultimately unsustainable.

The solution to this could be agroecology, which operates under the mantra of 'working with nature, rather than against it', restoring biodiversity and ecosystem functions in order to ensure productivity. These principles are already being put into action. As it stands, rice accounts for up to a third of our annual water use, but a low-water •

5 THINGS TO EAT LESS OF:



SUGAR The huge quantities of sugar produced around the world have a significant environmental impact. Sugar cane is one of the world's thirstiest crops, and the conversion of sensitive habitats like Vietnam's Mekong Delta into sugar monoculture has seriously harmed biodiversity.



TUNA
It's possible to purchase 'ethical' tuna, but it's difficult to navigate the various species and fishing methods in order to ensure it is sustainably sourced.
Skipjack is good, bluefin is bad. Pole-and-line is good, long line is bad. Your best bet is probably to stick to safer options if you fancy some fish.



AVOCADOS
Since avocados have become synonymous with a hip, healthy lifestyle, it's easy to forget that they are no friend to the planet. It takes around 272 litres of water to produce two or three avocados, and many of them are being grown in the drought-stricken farms of California.



SOY
Linked with everything from groundwater contamination to deforestation of the Amazon rainforest, soy is high up in the rankings of worst foods for the environment. But it's not the vegan munching on a soy burger who should feel bad – around 75 per cent of all soy is fed to livestock.



BEEF
While there are issues
with farmed meat in
general, beef is in a
league of its own. One
study estimated that
beef requires 28 times
as much land as the
same amount of poultry
and pork, as well as 11
times as much water
and it produces five
times as much
greenhouse gases.

"A TRULY ENVIRONMENTALLY FRIENDLY DIET RELIES ON MAJOR SYSTEMIC CHANGES, BUT INDIVIDUAL DIETS ALSO NEED TO CHANGE"

• agroecological method known as System of Rice Intensification (SRI) is increasingly being used to produce rice yields up to 50 per cent larger. Water is only applied to the rice when needed, compost is used instead of chemical fertilisers, and farmers weed by hand, instead of using herbicides. Using this method, Sumant Kumar, a farmer from the Indian state of Tamil Nadu, has smashed the previous annual rice-growing record by an astonishing three tonnes. Whether it involves rice,

BELOW: Agroecology involves working with nature and putting control back in the hands of small-scale farmers pigs, fish or apples, agroecology is about dismantling the current system and placing power into the hands of small-scale producers and family farms. If this is starting to sound a bit too 'eco-warrior' for your taste, it's worth noting that even the UN is behind this trend. "Modern agriculture, which began in the 1950s, is more resource intensive, very fossil fuel dependent, using fertilisers, and based on massive production. This policy has to change," declared UN representative Prof Hilal Elver back in 2014, explaining that it is agroecology that holds the key to a sustainable future.

INCONVENIENT TRUTHS

A truly environmentally friendly diet relies on major systemic changes, but individual diets also need to change. The variety of data on offer can give the impression of flip-flopping within the scientific community, but it's more indicative of the sheer complexity of the subject – not to mention the competing interests of stakeholders in the food industry. In fact, certain trends are clear.





RIGHT: Red meats, like beef and lamb, have a greater impact on the planet than chicken

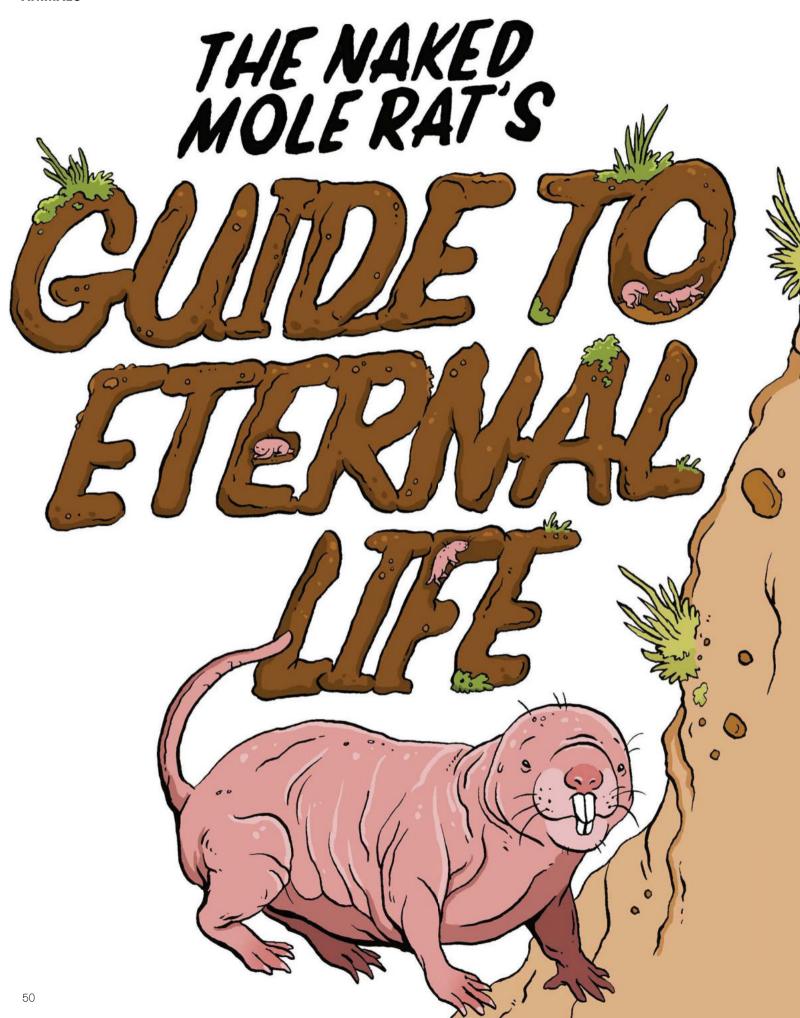
BELOW: People who follow vegetarian diets should still be aware of how their favourite foods affect the planet

Headlines about the evils of lettuce and veganism saving the world may seem misleading, but it would be disingenuous to pretend that farming animals isn't a problem. People in the West are eating too much meat, and as countries like China and India become wealthier, their demand for it is increasing. Dr Rajendra Pachauri, ex-chairman of the UN's Intergovernmental Panel on Climate Change called for one meat-free day a week as a way of personally making a difference, and this seems like a good place to start. Other sensible suggestions include choosing fish from sustainable or certified stocks, buying vegetables that store well, and avoiding food waste. The kind of mass switch to veganism envisaged by some studies is probably unrealistic, but relatively small changes in the way we eat can produce sizeable effects. We should be at a stage where suggestions like Pachauri's are not controversial, because while we may not have all the information, we certainly have enough to make a difference. •

Josh Gabbatiss is a science writer based in London. He tweets from @Josh_Gabbatiss



PHOTOS: GETTY X2, AGROECOLOGY FUND



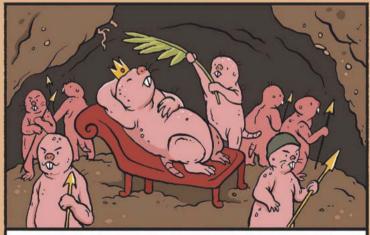
NAKED MOLE RATS AREN'T WESE WRINKLY RODENTS MIGHT JUST HOLD THE SECULIAR TO LONG AND HEALTHY HUMAN LINES WORDS: KAT ARNEY



Naked mole rats don't feel pain like other rodents do. Their pain receptors are less sensitive, which means they can put up with hotter, harsher conditions.



Unlike their rodent cousins, naked mole rats almost never succumb to cancer as they age. These wrinkly creatures can survive into their thirties, a span five times longer than expected for a mammal of their size.



Naked mole rats' cooperative social behaviour may contribute to their longevity. There is one breeding female called the queen, and the rest of the mole rats chip in to protect her and the colony from harm.



The babies are born with unusually well-developed brains, more like newborn primates than rodents.

Intriguingly, the make-up of their nerve cells is closer to humans than mice.

strangest looking animals on Earth. But their appearance belies a remarkable set of traits. Over the past few decades, scientists have discovered that this hairless rodent is immune to cancer, resistant to pain, capable of surviving without oxygen, and able to live for a remarkably long time.

Whereas most similarly sized rodents last only a few years (rats reach four years maximum), naked mole rats can survive into their thirties, five times longer than expected for their body size. The current record is held by 'Old Man', who was 32 when he finally passed away in 2010. Old Man wasn't even unusual, as most naked mole rats easily make it into their late twenties.

Unsurprisingly, this peculiar longevity has been capturing the attention of scientists around the world. What is this rodent's secret to long life, and might we even be able to harness it for ourselves? Let's go underground...

MEET THE MOLE RATS

Naked mole rats are actually neither moles nor rats, but a rodent more closely related to porcupines and guinea pigs. They live in large colonies beneath the East African desert, constantly tunnelling in search of the elusive but tasty plant roots that make up their diet.

Strangely for rodents, only a few animals in the colony are sexually active: a sole dominant queen who rules the roost, and a handful of lucky stud males. The rest stay as non-breeding workers responsible for digging, maintaining and guarding their twisting network of tunnels. This unusual lifestyle first caught the attention of researchers as far back as the 1970s, who brought wild naked mole rats from Africa to establish colonies in labs and zoos around the world.

One such colony can now be found at Queen Mary University of London. Here, I visit mole rat expert Dr Chris Faulkes, who takes me into a



stifling room full of interconnected transparent plastic pipes teeming with nearly 300 busy, pink bodies. The warm air buzzes with the constant sound of scratching – their teeth are continually growing, so they have to keep gnawing at the tunnel walls – interrupted with high-pitched squeaks and occasional scuffles.

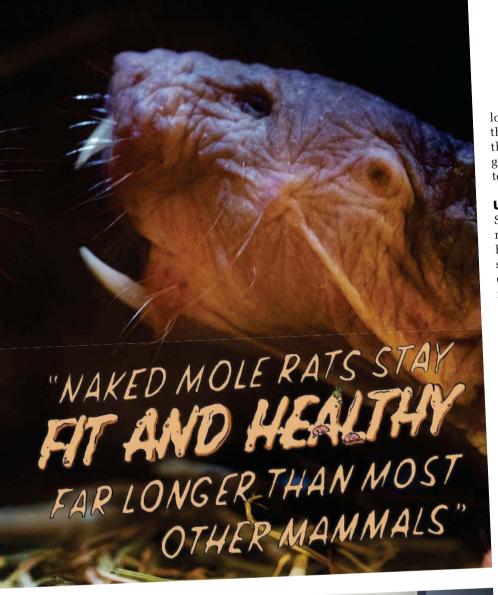
. Faulkes reaches into a nest box to retrieve a heavily pregnant queen. Looking at the wriggling rodent in his hands, I can't help thinking that it already looks like a caricature of a centenarian with its sagging, hairless skin. "They live in the dark – their looks don't matter!" he laughs. Even the babies share this ancient appearance, although apparently the oldest animals do have more papery, pale skin and a 'jowly' look about them. Naked mole rats also stay fit and healthy far longer than most other mammals, maintaining their youthful good looks and vigour for at least twothirds of their lifespan.

As Faulkes explains, the key to the naked mole rat's longevity lies in understanding their lifestyle and underlying biology. "Most people would agree that it's a whole combination of factors that all come into play," he says. "Naked mole rats have a

ABOVE: Their teeth can tackle a diet of roots and tubers, but also help the mole rats dig through soil

RIGHT: Dr Chris Faulkes with one of his naked mole rats

ORNA FAULKES ILLUSTRATIONS: LINDSAY LEIGH





low body temperature and a low metabolic rate, they're in a calorie-restricted environment, and they have a whole raft of biochemical and genetic differences that we're only just starting to unravel."

UNDER THE SKIN

Shielded from the scorching sunshine in their native Ethiopian landscape (or warmed by a heater in the laboratory), the mole rats' burrows stay at a constant 30°C. As a result, they've evolved to dispense with the effort of maintaining the body temperature of around 37°C that's found in most other placental mammals, instead conforming to the relatively lower temperature of the subterranean world around them. "The environment they live in is what drives a lot of their weird biology," explains Faulkes. "They don't need so much energy because they're not thermoregulating, so they can get away with eating much less."

There's a well-established relationship between having a lower body temperature and a longer life, and evidence from many species – including fruit flies, worms and mice – suggests that a low-calorie diet can significantly extend healthy lifespan. Exactly how this works isn't clear. Some researchers suggest that a low-cal, low-temperature lifestyle reduces the production of damaging chemicals called free radicals, which are created as cells make energy. Others think the explanation is more likely to lie in altered levels of hormones and other molecules that drive cell growth. The naked mole rat's vegetarian diet probably plays a role too. Their favourite foods are rich in chemicals known as polyphenols, which are thought to combat ageing and boost health.

And there are more tricks up the naked mole rat's wrinkly sleeve. Many mammals succumb to cancer as they get older, but mole rat tumours are vanishingly rare, with only a handful of cases documented in more than a thousand captive animals. In 2013, scientists discovered that this is at least partly due to naked mole rats having an unusually large and sticky version of a molecule called 'high-molecular-mass hyaluronan', which glues cells together.

As well as apparently making their skin super-stretchy so that they can squeeze through the tightest of tunnels, the hyaluronan seems to reinforce contacts and communication between a mole rat's cells, stopping them from running out of control and turning cancerous. Researchers are now investigating the underlying genes and molecular pathways responsible, to see if we can use this knowledge to increase human lifespan. Whether this 🗢

Could one of these other long-lived animals hold the key to living forever?



Living in the chilly Arctic seas, ocean quahog clams have such a slow metabolism that they can live for centuries. One clam, known as Ming, was thought to be 507 years old when captured. Ocean quahogs also don't seem to age once they've reached maturity – this is known as 'negligible senescence'.



BOWHEAD WHALES

Thought to be the longest-lived mammals, one male bowhead whale has been estimated to be 211 years old. Scientists studying the bowhead genome have discovered interesting variations in genes involved in cell growth, DNA repair, ageing and cancer, hinting at possible reasons for their longevity.



'IMMORTAL' JELLYFISH

Officially known as Turritopsis dohrnii, these jellyfish aren't strictly long-lived, but they do have the ability to completely regenerate in the face of starvation, injury or other stress. Adult jellyfish can shift all the way back to an embryonic state, effectively respawning and starting the game of life again.



Several species of bat can live for at least 20 years, but the Brandt's bat holds the record at 41. Its small size gives it the longest lifespan in proportion to body size of any mammal, and its longevity is thought to be down to mutations in two genes involved in its hormone system.



Galapagos and Aldabra giant tortoises are renowned for their impressive age and slow lifestyle. One Galapagos tortoise, Harriet, was reportedly collected by Charles Darwin, dying more than 150 years later in 2006. An Aldabra tortoise, Adwaita, was estimated to have died at 255, which would make him the oldest terrestrial animal known to science.



• means we would also end up with the same baggy, stretchy skin as the naked mole rats remains to be seen.

A MATTER OF LIFE AND DEATH

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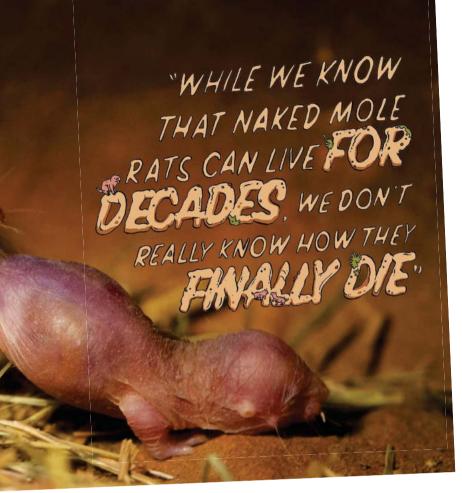
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There's a further question that needs answering. While we know that naked mole rats can live for decades, we don't really know how they finally die. Infections are rare, barring the odd tummy bug, and the most common cause of death is violence. Fights are relatively uncommon, but those sharp teeth can be lethal. Other than that, it's a mystery.

"I had an old one die the other day, but by the time I found him it wasn't very pleasant as the room is so warm," Faulkes recounts. "What is it that packs up first? Is it their ticker or something else? Nobody really knows." He and his team have found no signs of heart problems or cardiovascular disease in their older animals. Naked mole rats also seem to avoid the typical muscle wasting that sets in with old age until their very late twenties.

To find out why, the researchers are investigating mole rat mitochondria – the microscopic 'power stations' inside cells. Unlike other cellular structures, mitochondria have their own DNA that contains a handful of genes. This DNA tends to pick up damage over time, eventually causing mitochondria to wind down in later life.

Faulkes and his team have found that muscle fibres in older naked mole rats look just as good



as those in younger specimens, and are bursting with young-looking mitochondria. Furthermore, certain mitochondrial genes are much more active than those in mice, and there are many more copies of the mitochondrial DNA. He thinks this extra DNA dose might be buffering the effects of genetic damage, keeping mole rat mitochondria powering on well into old age.

GENETIC SECRETS

Dr João Pedro de Magalhães and his team at the University of Liverpool have also gone in search of the secrets of longevity. They've been digging into the DNA of long-lived animals, including the naked mole rat. As might be expected for a species with such a weird lifestyle and biology, mole rats have plenty of fascinating genetic adaptations for life in stuffy, pitch-black burrows. They also have some intriguing traits that might help to explain LORNA FAULKES their lifespan, right down to the cellular level.

"We find differences in genes involved in the response to DNA damage associated with ageing, compared with other animals," says de Magalhães, "and we know that cells from naked mole rats are

ABOVE: Only the mole rat queen gives birth to babies, but the workers will help care for the young

more resistant to stress and damage." This explains how mole rat cells seem to shrug off toxic chemicals and other assaults on their DNA. And if that fails, there's a further defence mechanism: just kill off any damaged cells as quickly as possible.

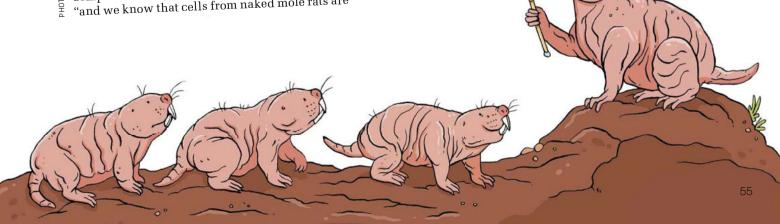
"Mouse cells continue to divide even with DNA damage, which can cause cancer, but naked mole rat cells don't," he says. "In mice, this damage doesn't really matter because their evolutionary priority is to reproduce very quickly and then die. But because naked mole rats live for longer, even a cell with a little bit of DNA damage has to be prevented from dividing and killed off."

Now, de Magalhães wants to use genetic engineering to create mice carrying naked mole rat versions of certain genes. This would help him to find out whether these genes affect the mice's ability to repair damaged DNA or other processes that could contribute to a long and healthy life. And once we find out, we might be able to use these effects for ourselves. "We may be able to apply these biological tricks to retard ageing or agerelated diseases in humans," he says.

With their amazing ability to cheat death and stay spritely for years, it's unsurprising that naked mole rats have caught the eye of companies and entrepreneurs, particularly Silicon Valley tech gurus who seem determined to live forever. Google's secretive Calico Labs has reportedly established its own colony, hoping to develop new anti-ageing drugs based on its discoveries.

Whatever they find, some of it may already have rubbed off on Faulkes. "One of my friends told me I looked 10 years younger than my age," he laughs. "I told them it must be something coming from the mole rats!" 😉

Kat Arney is a London-based science writer and broadcaster. . Her book Herding Hemingway's Cats: Understanding How Our Genes Work (£9.99, Bloomsbury Sigma) is out now.





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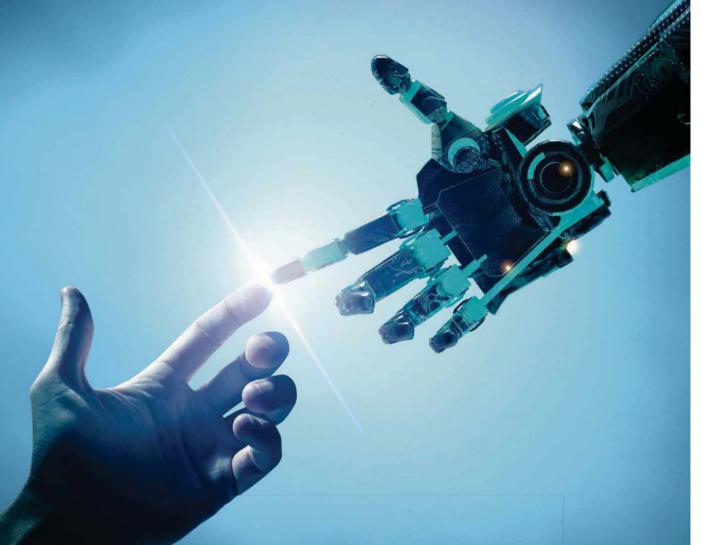
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UNITATURAL SELECTION

Survival of the fittest favours those animals that are best suited to their environment. But what happens human interference is added into the equation?

WORDS: IULES HOWARD

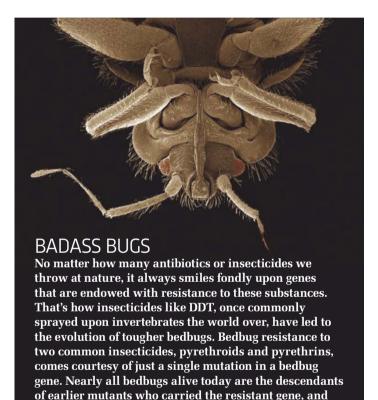


MINI MOUTHS

In 1935, Australian scientists came up with an exciting new method to control problematic crop pests. They decided to introduce cane toads from the Americas. The cane toads soon roamed away from their original introduction site, and now inhabit much of eastern Australia. The toads are loaded with deadly poison, making them lethal to many predators that eat them. Yet the toads have had a surprising effect on two species of snake, the green tree snake and the red-bellied black snake. Their jaws, over many generations, have appeared to shrink. Those snakes with smaller jaws eat smaller toads, and therefore ingest less poison.

WHITTLED WINGS

As traffic on many of the world's roads increases, some birds, such as cliff swallows, are already adapting. In a 2012 study incorporating three decades of data, the average wing length of cliff swallows nesting upon motorway overpasses was observed to have reduced by a tiny (but nonetheless significant) 5mm. The reason? Short wings accidentally endow birds with a more dynamic flying style, allowing for enhanced dodging and weaving, meaning they can avoid vehicles better than longer-winged counterparts. These small-winged variants have since flourished and, incredibly, observations of cliff swallow roadkills are down to a quarter of what they once were.



have hence become extremely difficult to eliminate.

SHRINKING TEETH

Modern creatures are survivors, chiselled through natural selection. But humans also have the potential to control which animals live and die, leading to what is called artificial selection. The effect of a century of poachers killing elephants with the largest tusks is already having an impact, with more elephants either being born with the genes for smaller tusks or no tusks at all. In Mozambique's Gorongosa National Park, for example, more than 33 per cent of all females are tuskless. Back in 1930, just 1 per cent of Africa's elephants were tuskless.



ISLAND LOVERS

When Darwin visited the Galápagos, he realised that remote islands are hotbeds of evolution, seeded by stowaways that reach their shores and adapt to local conditions. In 1971, scientists simulated this by moving five pairs of Italian wall lizards to an uninhabited Croatian island. Revisiting the island 30 years later, they found that the lizards, originally insect-eaters, had evolved a primitive form of herbivory. Their gut had changed to include fermenting chambers, and their jaws had become stronger.

The Bolivian salt plains hide vast reserves of lithium. With demand for rechargeable batteries set to soar, could this be the site of a new gold rush?

WORDS: HAYLEY BENNETT TRANSLATION: ADRIANA CASTRO PHOTOS: DANY KROM/REDUX/EYEVINE



igh up in the Andean

Mountains in Bolivia is a

vast expanse of white

desert, the world's largest

salt flat: Salar de Uyuni.

Stretching 160km from

west to east, its cracked surface heals during the rainy season to form a giant natural mirror. Until recently, this extraordinary environment had kept all but migrating flamingos, salt rakers and the most intrepid of tourists at bay. Just below the surface, however, is something that the mining industry is itching to get its hands on: 10 million tonnes of lithium. This soft, silvery metal is the stuff of the rechargeable batteries that power our smartphones and laptops.

In the so-called 'lithium triangle' covering the borders between Bolivia, Chile and Argentina, lithium is extracted from brine beneath the crusts of salt plains. These three South American countries alone hold 56 per cent of the world's lithium stores. Bolivia's lithium is thought to have leached from the surrounding Andes into a prehistoric lake that dried to form the present-day salt flat. It contains more lithium than even the most productive flat, Chile's Salar de Atacama. The Bolivian government is shelling out millions to help unlock the potential of this huge, untapped resource, but whether it all pays off may depend on the future of the electric car industry.





EARTH

PREVIOUS PAGE: Raúl
Martinez at an evaporation
pool, where lithium
carbonate is concentrated
from brine. Miners must
protect their skin and eyes
from the Sun's UV radiation
and the surface glare



MAIN IMAGE: Evaporation pools, separated by levees, concentrate the lithium

BELOW RIGHT: Lithium-rich brine is pumped from beneath the crust



MINING THE BRINE

Lithium carbonate is extracted from the salt desert by piping brine from below the crust into large evaporation pools. Three litres of Salar de Uyuni brine contain less than a gram of lithium metal, so it is concentrated under the glare of the Sun before being collected for processing. The lithium at Salar de Uyuni is also bound up with magnesium, which has to be removed before the lithium can be turned into electrodes and electrolytes for batteries.

Right now, there is only one working pilot plant at the salt flat, where, as former director of communications for the plant, Raúl Martinez, explains, 99.7 per cent pure, battery-grade lithium is being produced. "This project demonstrates that the Bolivians have all the potential to obtain lithium carbonate of commercial and battery-grade in the salt flats," he says. However, the state mining company Comibol may need to scale up its operations. It shipped less than 30 tonnes of lithium carbonate in 2016, making the target of 10,000 tonnes by 2021 seem like a stretch. Bidding for construction of a second plant, designed by German company K-UTEC, is underway.







LEFT: A young boy amuses himself by playing football while his dad makes bricks for building salt hotels

UNCERTAIN TIMES

The Bolivian government plans to plough \$925m into the lithium industry by 2019. President Evo Morales dreams of building a high-tech future for his country, based on manufacturing smartphone and electric car batteries. However, outsiders claim he needs foreign investment, and so far this hasn't been particularly forthcoming. What's more, there's no guarantee of lucrative markets like China being reliant on lithium in the future. Prof Martin Bertau, director of the Institute of Technical Chemistry at TU Bergakademie in Freiberg, Germany, thinks lithium batterypowered cars may only be a short-term solution for China, while another potentially greener technology based on methanol fuel cells ramps up. "If direct methanol fuel cell cars emerge [in China], lithium electrical vehicles may lose their significance overnight," he says. "It is this scenario that truly will not be helpful for Bolivia."

There also remains uncertainty over the environmental damage that could be caused by widespread lithium mining on the salt flat, with accusations flying back and forth between mining and environmental organisations.

According to Martinez, all mining activities at Salar de Uyuni must comply with state regulations to reduce their environmental impact. The Bolivian National Evaporite Resources Authority has switched from lime-based to sulphate-based technology because this produces less sludge, although research on the impacts of sulphate in this environment is scarce.

TOP RIGHT: The Salar de Uyuni salt flat covers over 10,000 square kilometres

MIDDLE RIGHT: Compounds extracted from the brine are stored in large silos

BOTTOM RIGHT:

Battery-grade lithium
carbonate

MAIN IMAGE: This aerial shot gives a bird's-eye view of a brine-filled evaporation pool



SUPPLY AND DEMAND

Demand for lithium in batteries has risen on average by 20 per cent a year since 2000. The most powerful Tesla Model S electric car (the P100D) carries a 100kWh rechargeable battery, with each 6kWh of performance requiring around 5kg of battery-grade lithium carbonate.

What makes the market situation unpredictable is that lithium has other uses the most important being for strengthening and coatings in glass and ceramics. It's almost impossible to predict accurately what the future of the lithium industry will look like, but earlier this year, Bertau published a paper on lithium supply and demand in the journal Energy Storage Materials that gives us a short-term idea. 140,000 tonnes of lithium carbonate were produced in 2014. If electric cars really take off, demand could reach 300,000 tonnes by 2020, or less than 200,000 tonnes in a more modest scenario. Bertau thinks the modest scenario is more realistic but, either way, it looks like lithium is going to be in demand for some time yet. What this will mean for the Bolivian mining industry, and those who depend on it, remains to be seen. •











: Jeff Forshaw and Brian Cox : **GUIDE TO THE COSMOS**



Part IV of IV

BEFORE THE BIG BANG

The beginning of space, time and everything

About this series

In this exclusive four-part series, physicists Jeff Forshaw and Brian Cox introduce us to the biggest ideas in modern physics and cosmology. What is the nature of time? What is everything made from? What happened before the Big Bang, and how will the Universe end? We'll delve into the deepest questions concerning the very essence of space, time, matter, and reality itself...



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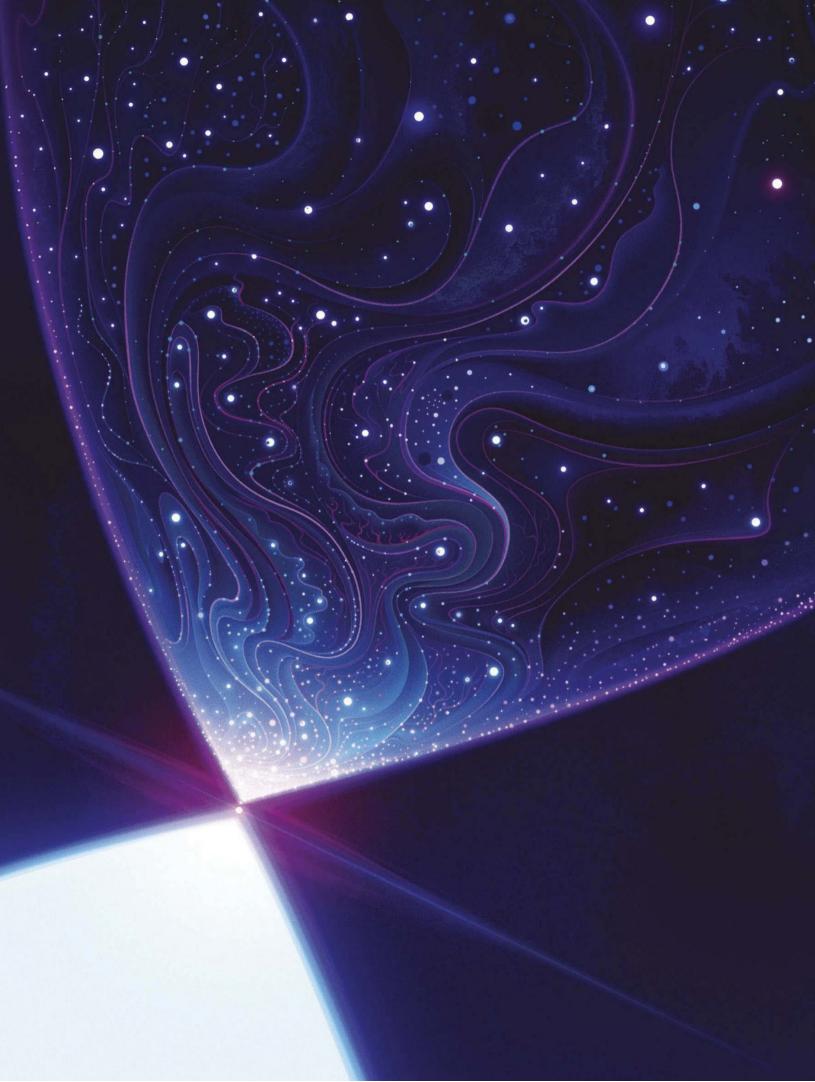
robably the most audacious idea in the whole of science is that it is possible to track the evolution of the Universe starting from

a time, almost 14 billion years ago, when everything we see around us today was squeezed into a space far, far smaller than the size of a proton. It's an astonishing claim, and in this final article in our series we will piece together the remarkable story of the birth of our Universe. •

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"The Universe was simple at the time of the Big Bang"

◆ The vastness of the cosmos is hard to appreciate, but take a close look at the map of the Universe shown on the opposite page. Each tiny dot in this image is a galaxy, and each galaxy typically consists of hundreds of millions of stars. Our own Sun is one such star, residing in the Milky Way, and the Andromeda galaxy is our nearest neighbour, at a mere 2.5 million light-years away.

This galaxy map was created by astronomers from the Sloan Digital Sky Survey, and it covers about one-third of the sky: it's just a small portion of everything that's out there. Apart from being mind-blowing in its scale, the map is also noteworthy for the fact that the galaxies make a wispy pattern, with strands and clumps and voids. Wouldn't it be an achievement

to be able to explain how that wispy pattern came to be? Let's put that question on hold for the moment. As we'll find out, the observed structure of the Universe can be explained using a theory that may well be the jewel in the crown of modern cosmology.

AN EVOLVING COSMOS

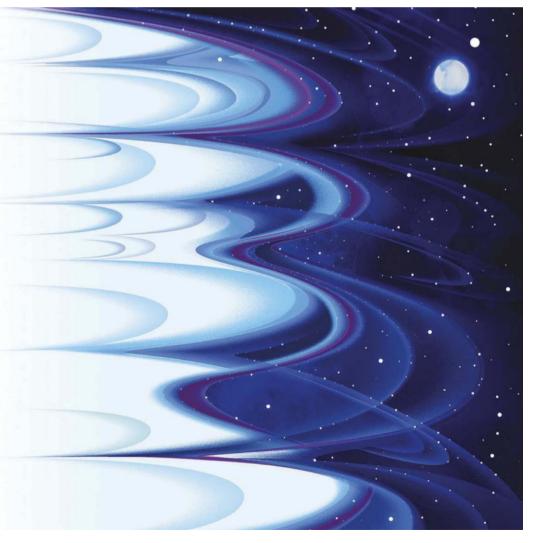
The Universe wasn't always like it is now. A little less than 14 billion years ago, the Big Bang happened (see 'The key idea'). This is the time when all of the elementary particles that were destined to produce the stars and galaxies were first created. The Universe was simple at the time of the Big Bang (it's the present-day Universe that is complicated and hard to understand). This is good news, because it means cosmologists can do the calculations to work out how things evolved.

At the time of the Big Bang, the Universe contained a hot, almost featureless gas of elementary particles. That word 'almost' is absolutely crucial here, because the density of particles in the gas was not entirely uniform: some regions had a marginally higher density than others. Knowledge of this pattern of density variations is enough for cosmologists to evolve the gas forwards in time.

At first, this gas just cooled and expanded but, gradually, gravity caused the higher density regions to draw in more matter and become increasingly dense. After a few hundred million years or so, some clouds of hydrogen became dense enough to ignite and burn via nuclear fusion - these were the first stars. Cosmologists can compute how the stuff of the Universe evolved from a hot, dense gas all the way to the formation of galaxies: the key input to their calculations is knowledge of those original variations in the density of the gas. But, of course, to know those requires some idea of what actually caused the Big Bang in the first place.

BACKGROUND NOISE

Over the past 15 years or so, cosmologists have become increasingly confident in one particular theory for the origin of •

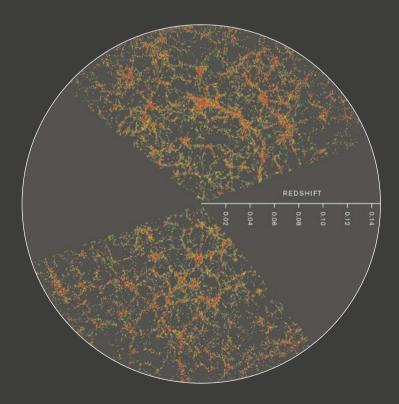


The key idea

OUR UNIVERSE IS AN EXPANDING FRUIT CAKE

The Big Bang is like baking a fruit cake. As the cake expands, the pieces of fruit all move apart from each other, and so it is with the Universe: space expands and the galaxies all move apart. The idea that space is malleable and can expand may seem a little weird, but it is a consequence of Einstein's Special and General Theories of Relativity, which we met in the first article in this series. The Big Bang is analogous to the time when the pieces of fruit were very close together, just after the cake was popped into the oven. Today, the cake is still cooking, and the expansion of our Universe even appears to be speeding up. One common misconception regarding the Big Bang is that everything expanded away from a point in space. This is wrong. Indeed, it is likely that the Universe was vast, even at the time of the Big Bang. It was vast and of very high density, which means the particles were very close together. Rather like the case of a very large piece of raw dough prior to baking, when the pieces of fruit were very close together.

THE SLOAN DIGITAL SKY SURVEY



A map of the Universe from the Sloan Digital Sky Survey. Each dot represents a galaxy and the red regions have a higher density of galaxies. The Milky Way is at the centre and the redshift value indicates how far away the galaxies are (the most distant are almost two billion light-years away)

Glossary

X BIG BANG

This is the time when the Universe was densely populated with elementary particles moving around in a very hot gas. It occurred almost 14 billion years ago.

BUBBLE UNIVERSE

This is a region of the Multiverse in which inflation has halted, giving rise to a Big Bang. Our visible Universe could be such a region.

× COSMIC MICROWAVE BACKGROUND

These are photons that have been travelling in straight lines across the vastness of space since a time 380,000 years after the Big Bang.

X INFLATION

This was the time before the Big Bang when space underwent an ultra-rapid expansion.

X INFLATON

This field pervaded space and caused inflation to occur. The decay of the inflaton is what generated the particles of the Big Bang.

X MULTIVERSE

In some theories of inflation, the entire Universe is called the Multiverse and it contains a large number of bubble universes. Each bubble universe is separated from the others by a vast, rapidly-expanding space.

VISIBLE UNIVERSE

This portion of the Universe includes stars, galaxies and everything that we can see. The Universe is bigger than this: we can't see everything because the light from the most distant objects has not yet reached us.

As if this weren't amazing enough, there is even more impressive proof for the theory of inflation: it can also predict the fine details of what is known as the 'cosmic microwave background' (CMB). Essentially, this is the cooled, faded afterglow of the Big Bang, which gives us a photograph of the Universe when it was just a few hundred thousand years old.

The CMB is light that has been travelling unimpeded across space since it started its journey 380,000 years after the Big Bang. At this point in time, light suddenly stopped interacting with the surrounding gas and headed off in largely uninterrupted straight lines. Today, we can measure this light in the form of microwaves (it actually started out as infrared light, but has been stretched on its journey across space due to the expansion of the Universe).

By measuring the CMB, cosmologists are able to map the density variations in the cooling gas that existed shortly after the Universe was born (see the image on the right for the pattern of microwaves arriving at the Earth today). We can then compare these observations with theoretical computations. If we suppose that the Big Bang started out with the pattern of density variations predicted by inflation, the computations are found to give the exact CMB that we observe



"Dark energy would cause space to accelerate in its expansion"

in reality, which is serious evidence in favour of inflation. But what exactly is inflation?

COSMIC TREACLE

The theory of inflation emerged in the early 1980s, and at first had nothing to do with the distribution of galaxies or the CMB. Instead, it began with the idea that empty space might be filled with an invisible 'scalar field' – a kind of cosmic treacle. This field would permeate all of space, like a still ocean, and ripples in the field would be manifested as particles.

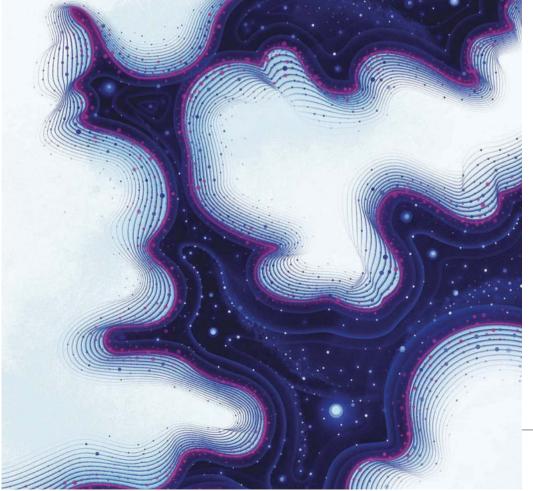
This idea is familiar to particle physicists because one such field is the Higgs field, accompanied by the Higgs boson particle (we met this in last month's article). Without the Higgs field, elementary particles would have zero mass and would zip around at the speed of light, so atoms would not form. Today, the Higgs boson has been observed at the Large Hadron Collider.

The existence of the Higgs field also means that there should be an energy associated with what we think of as empty space, and this energy can act as a source of 'dark energy'. This dark energy would cause space to accelerate in its expansion. The trouble is that current theories in particle physics seem to suggest that this accelerated expansion should be far faster than astronomers observe. The fact that, today, the amount of dark energy is much less than expected is one of the biggest mysteries in particle physics.

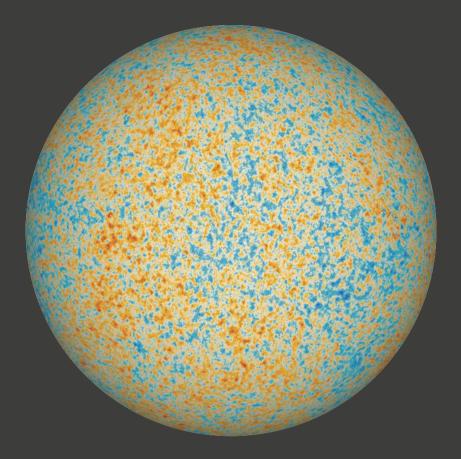
Nevertheless, the possibility that other, similar fields might exist led cosmologists to consider that the Universe might well have undergone a period of ultra-rapid expansion sometime in its past. The remarkable thing is that this idea turns out not only to be feasible, but also offers an explanation for the origin of the Big Bang itself.

NEW BEGINNINGS

The basic idea of inflation is that empty space was once filled with an 'inflaton field', and that the energy stored in this field caused the space to rapidly expand. This expansion was most likely so rapid that, before too long, the Universe was a cold and •



MICROWAVES ARRIVING AT EARTH TODAY



The microwaves that bathe the Earth today, as measured by the Planck satellite. The colours represent the temperature of the microwaves, which vary by only around 100-millionths of a degree. These tiny temperature variations are directly related to the density variations in the gas that existed 380,000 years after the Big Bang.

Cosmology in five steps



1

Many cosmologists
think that the Big Bang
was preceded by a
period of rapid
expansion, called
inflation. This inflation
was caused by the
energy stored within
an all-pervasive field,
called the inflaton field.



7

As the energy drained away from the inflaton field, the inflation ended and gave way to the Big Bang. At this time, almost 14 billion years ago, the Universe contained a hot, dense gas of elementary particles.



3.

Quantum effects during inflation meant that these particles were not spread out with perfect uniformity. Instead, the gas was slightly denser in some regions than in others.



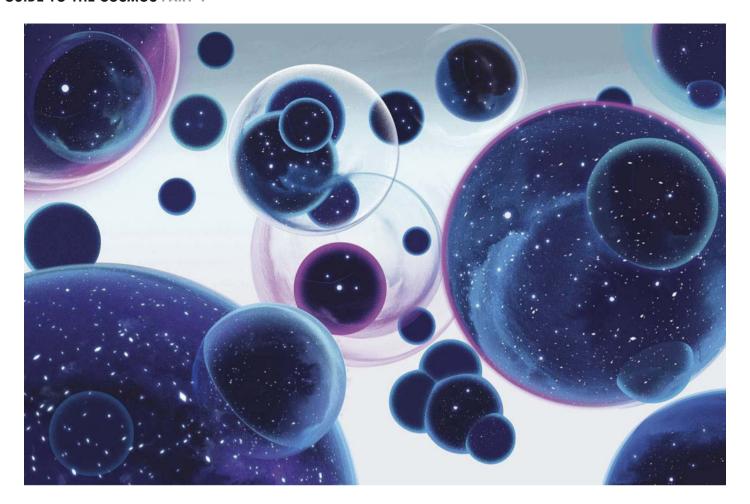
4

These density variations acted as the seeds out of which galaxies grew.
Starting from these original seeds, cosmologists are able to compute today's observed pattern of galaxies (and the cosmic microwave background).



5.

It is possible that we live in a bubble universe which is just one of many in the entire Universe (the Multiverse). It is even conceivable that the laws of physics are different in each bubble universe.



• empty place as everything rushed away from everything else. After a time, this period of rapid expansion drew to a close as the energy stored in the inflaton field steadily drained away, leaving behind a Universe filled with a cold gas of inflaton particles. These inflaton particles then decayed into other, more stable, particles and, in doing so, they generated the Big Bang, as the energy locked away in the cold gas of heavy inflaton particles got converted into a hot gas of lighter particles.

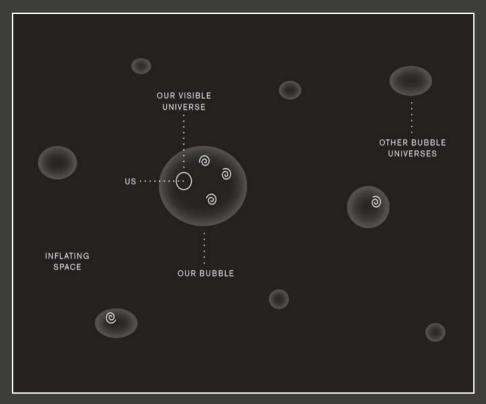
The idea of inflation was initially attractive to cosmologists because it generates a big Universe (due to that early phase of rapid expansion). However, it wasn't too long before they realised that the theory has much more to offer: it also predicts the pattern of density variations at the time of the Big Bang. In other words, it offers a detailed description of how the matter was spread about at the time of the Big Bang, and this (as we've discussed) is in precise accord with the patterns seen in the observed galaxies and cosmic microwaves.

 \times

"In around 100 billion years, the Milky Way will be part of a single supercluster of galaxies"

This stunning success of inflation arises as an unavoidable consequence of quantum physics. The mathematics allows us to consider going back to a time, just before the Big Bang, when the portion of space that was destined to grow into the entire visible Universe was less than a billion times smaller than a single proton. This is utterly mind-boggling but there appears to be no impediment to calculating what happened at this time.

Crucially, the inflaton field was not a perfectly still ocean – it had ripples in it. These ripples were generated as a consequence of Heisenberg's Uncertainty Principle, a key result in the theory of quantum physics (see Part II of this series). Heisenberg's principle tells us that nothing can ever be entirely still – even empty space is fizzing with particles that appear and disappear from nowhere (that fizzing is measured today in particle physics experiments). So, the inflaton field must have had ripples, and these were translated into corresponding ripples in the density of matter at the time of



We may live in a bubble of slowly-expanding space embedded in a much larger and still rapidly-expanding space that's undergoing inflation

"We are privileged to be living in an epoch when we are able to learn so much about the wonders of the cosmos"

the Big Bang. How wonderful that this extraordinary science is writ large on the sky and that we are so fortunate to be here to decode the message.

With inflation, we now have an explanation for the origin of the Big Bang and a new way of thinking about how our part of the cosmos came to be. It could even be that inflation was ongoing for a very long (possibly infinite) period of time before it halted in the region of space destined to grow into the Universe we see around us. In that case, the Big Bang was not the beginning. Rather it was just a moment in the history of the Universe.

Looking to the distant future, the fact that space is today slightly accelerating in its expansion implies that the Universe will never end. It will continue to expand forever, becoming ever more dilute and cold. In around 100 billion years, the Milky Way will be part of a single supercluster of galaxies, and all other galaxies will be racing away at such a speed that light from them could never reach the Earth. This means that astronomers of the far future would

have no distant galaxies to observe — to them, the Universe would seem a much duller place than we know it to be. We are privileged to be living in an epoch when we are able to learn so much about the wonders of the cosmos and its origins.

There is a final, mind-boggling twist to the story of inflation. We have just said that inflation might have been continuing forever before the Big Bang. It is also possible that inflation did not stop everywhere in the Universe at the time of the Big Bang. It may well be that we live in a bubble of slowly-expanding space embedded in a much larger and still rapidlyexpanding space that's undergoing inflation. There may even be other bubble universes like ours, rushing away from us at an unimaginable speed. According to some ideas in theoretical physics, it is conceivable that the laws of physics are different in each of these bubble universes. In other words, every variant on nature's laws is played out somewhere in the vastness of this Multiverse. Now there's a thought. •

Jeff Forshaw is professor of particle physics at the University of Manchester. He has co-authored three popular science books with Brian Cox.

Brian Cox is professor of particle physics at the University of Manchester and the Royal Society professor for public engagement in science. His BBC TV and radio work includes Wonders Of The Universe, Forces Of Nature, Stargazing Live and The Infinite Monkey Cage.

DISCOVER MORE

To learn more about the strange workings of the quantum world read Brian and Jeff's *The Quantum Universe: Everything That Can Happen Does Happen* (£9.99, Allen Lane).

Brian and Jeff's latest book is *Universal:*A Guide To The Cosmos (£25, Allen Lane).

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HELEN CZERSKI ON... WHAT CAUSES TURBULENCE?

"PLANES CAN COPE WITH TURBULENCE, SO ALTHOUGH MY TEA MIGHT GET SPILT, THERE'S LITTLE DANGER"

or me, being allocated a window seat on a plane is like being given a front row ticket to the majestic show of the sky. We spend our lives pootling

about at the bottom of the atmosphere, but a flight gives us a chance to appreciate the sky from within. Still, I'm well aware that my eyes can only detect a tiny fraction of what's going on. And there's no better reminder of that than the familiar announcement: 'the captain has requested that we turn on the fasten seatbelt signs', just before the buffeting starts. Not many people like turbulence, and its seemingly unpredictable nature just makes it worse. Yet when I'm strapped into my seat and staring out across the wing, the vast, blue sky doesn't seem to be in turmoil. In fact, everything looks quite still. What causes the turbulence and why does it occur?

Turbulence is a reminder of what's holding the plane up: vast hordes of air molecules bouncing off the underside of the wings. If the plane passes through a region where a column of air molecules is flowing up or down, the plane gets carried along with the flow. But winds travel horizontally - the atmosphere is generally stratified, which means that it tends to stay in layers. To bump a plane around, you need to disturb those layers, and there are two ways of doing it.

The first is convection, which is common near clouds. Air can be heated either by the ground or by the energy given off when water vapour condenses. Warmer air is less dense than its surroundings, so tends to rise, breaking the layered structure. But convection is only responsible for about a sixth of the turbulence experienced in planes. The second mechanism is far grander and far more unexpected.

What I can't see, when I look out of the window, are the layers of the atmosphere moving over each other. Winds travel at different speeds and possibly in different directions as you go upwards. The invisible

beasts of the sky are the jetstreams. These fast-flowing rivers of air snake across the Earth at exactly the altitude of most planes. Their discovery made a huge difference to aviation – a plane can hop on to this conveyor belt to speed up a transatlantic journey by an hour or so. But there's a downside for the turbulence-haters.

Think about when you blow onto a cup of tea: the air pushes up waves on the tea's surface. That's because a fast-moving fluid (air) is moving over a slower one (water). The same thing happens up in the air - when a faster fluid (the jetstream) moves over a slower fluid (the still air below), you get waves in the boundary between them. These waves march slowly across the sky, completely invisible to us. The peaks can be separated by many kilometres, and the greater the difference in wind speed between adjacent atmospheric layers, the more likely the waves are to form. Like any waves, if

they grow steep enough, they will break,

generating complex swirling patterns as

cause of most clear-air turbulence - gigantic breaking atmospheric waves. They're hard to forecast, and the plane's radar can't see them. But planes are built to cope, so although my tea might get spilt, there's little danger associated with them.

If you don't like turbulence, this probably isn't much consolation. But I love looking out of a plane window and imagining the waves lurking out there, especially if I'm in an eastbound plane in the core of a jetstream.

Since the patches of turbulence are relatively small (about five minutes of flying time on average), I know that the bumping will pass. And I reckon a bit of turbulence is worth it, just to experience what the sky is hiding from our eyes. •



Dr Helen Czerski is a physicist

and BBC presenter. Her latest

book is Storm In A Teacup.

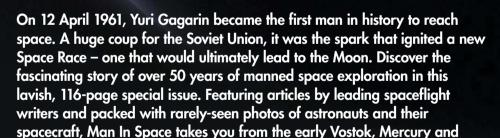
NEXT ISSUE: HOW PRESSURE

HELPS SEAL THINGS

ILLUSTRATION: KYLE SMART

77





Gemini missions to the International Space Station and beyond.











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DR ALASTAIR CHNN



Environment/ climate expert

DR PETER I BENTLEY Computer scientist, author



PROF ALIC Psychologist, sleen expert



CHARLOTTE Chemist, science writer Zoo director, conservationist



PROF ROBERT Physicist, science writer





DR HELEN SCALES Oceans expert, science writer



DR CHRISTIAN IARRETT Neuroscientist, science writer



DAVIES Heath expert, science writer



DR AARATHI PRASAD



JULY 2017 EDITED BY EMMA BAYLEY





Can plants get cancer?

YASMIN CAINE, CHESHIRE

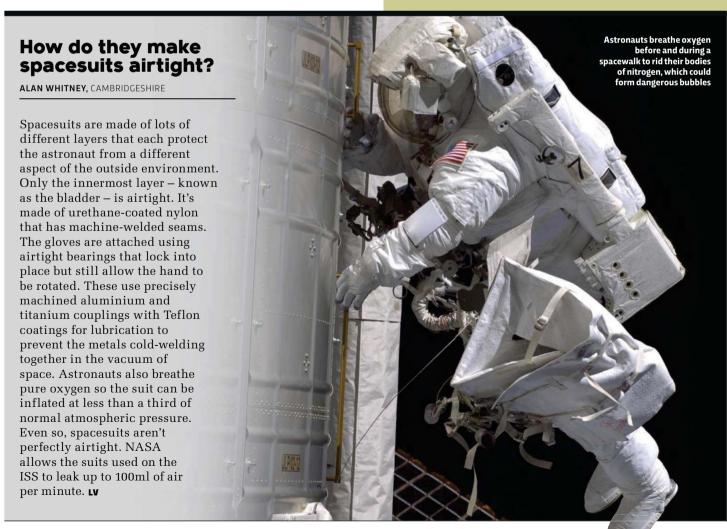
Yes. Crown galls are a kind of plant cancer, caused by the bacterium *Agrobacterium tumefaciens*. This causes uncontrolled growth of plant cells around the infection, just like a tumour. Other tumours can be triggered by fungi or physical damage. But plant cells are anchored in place by the cell walls, so plant cancers never spread far or metastasise to other tissues. LV

How do microbeads affect fish?

SUSIE ADAMS. PORTSMOUTH



There's no doubt that fish and other aquatic animals eat plastic fragments (under 5mm). These include 'microbeads' that are added to toiletries and household products, as well as fibres washed from synthetic clothing. A recent study found three-quarters of flatfish in the River Thames have eaten microplastics. Even deep-sea animals have synthetic fibres in their guts. The impacts of this are complex. Some animals suffer from blocked digestive tracts, leading to starvation. Another concern is poisoning from microplastics coated in toxic chemicals. There's still much we don't know about exactly how plastics and toxins accumulate in food webs. HS



The consequences of a second moon orbiting the Earth depend on how massive that moon is and how far from the Earth it orbits. The most obvious effect would be that the ocean tides would be altered. Tides could be either smaller or higher and there could be more than two high tides per day. If the gravitational influence of a second moon were extreme, it could lead to phenomenally huge ocean tides (up to a kilometre high) which would also result in frequent tsunamis. It could also lead to enhanced volcanic activity and earthquakes. AGU

IN NUMBERS

8

The number of years that orangutans can nurse their offspring – the longest time of any wild mammals.

1/

The number of seconds (±7 seconds) that all mammals take to defecate, regardless of size.

8

The percentage of male sheep that are homosexual.



Why do cats like small spaces?

MEGAN JACKSON (AGE 9), ABERGAVENNY

Cats can spend 18 hours a day sleeping. As they are solitary animals, they want a safe hiding place to snooze.

But a cat curled in a tiny box, even out in the open, is probably just avoiding your cold floor. Cats are happy in room temperatures around 14°C warmer than is comfortable for humans, and if there isn't a convenient sunbeam to lie in, they will make do with a cosy shoebox. LV

THE THOUGHT EXPERIMENT

HOW CAN I SURVIVE A ZOMBIE APOCALYPSE?



1. HEAD FOR THE HILLS

The spread of zombie disease can be modelled using epidemiological simulations. A 2015 study at Cornell University found that cities would be almost completely infected within a week but remote mountains would be untouched after four months. The reproduction ratio (RO) is the average number of new infections that each zombie creates. If RO is between zero and one, the epidemic will eventually die out.



2. LAY LOW

If the zombies need to eat brains to survive, humanity may be able to simply wait out the crisis. A human brain only contains a maximum of around 2,000 calories, so even the slow and shambling kind of zombie will need to feed every few days just to maintain its metabolism. And any humans that are eaten can't rise to become new zombies, so the disease would also spread more slowly.



3. FIGHT BACK

Conversely, a 2009 study at the University of Ottawa predicted that even if a cure for the virus is found, zombies will eventually overwhelm the population by infecting us faster than we can be treated. Of the possible scenarios, the only one with a happy ending gave us just 10 days to destroy all the zombies, with a series of increasingly devastating counter-attacks.



Can your body be older than your age?

DENISE BEST, OXFORD

While age is usually thought of as just the number of years you've been alive, people with identical ages often look - and seem – very different. In 2015, scientists at King's College London published research suggesting that measuring the activity of around 150 specific genes gives a measure of 'biological age' linked more strongly to longevity than mere chronology. But genetic activity is only one factor differentiating biological and chronological age. Exercise, diet and weight can also make a big difference. This has led to various questionnaires – such as the BBC's online quiz 'What's My Real Age?' (bit.ly/age_quiz) - which can give clues about your current 'real' age, and offer advice on what you can do about it. When using these quizzes, do bear in mind that some of the measures are still controversial. RM



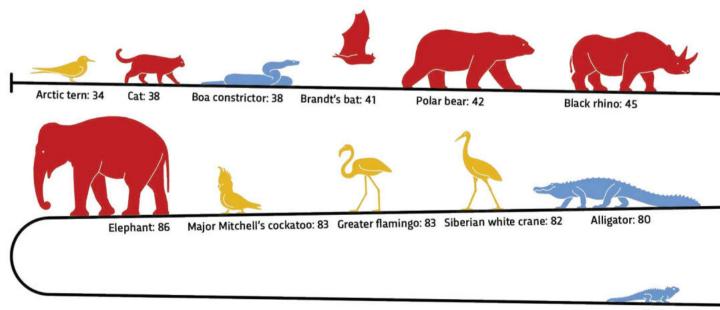
Why do your ears pop?

ANTONIO HARDY, LONDON

The air pressure on your eardrum is normally balanced because your middle ear is connected to your sinuses via a narrow duct called the Eustachian tube. If the outside air pressure changes too quickly though (in an aeroplane coming in to land, for example), the Eustachian tube can't equalise the pressure fast enough and the eardrum bows in or out. The popping sound occurs when the pressure rebalances and the eardrum suddenly flips back. IN

TOP 10

LONGEST LIVING LAND VERTEBRATES*



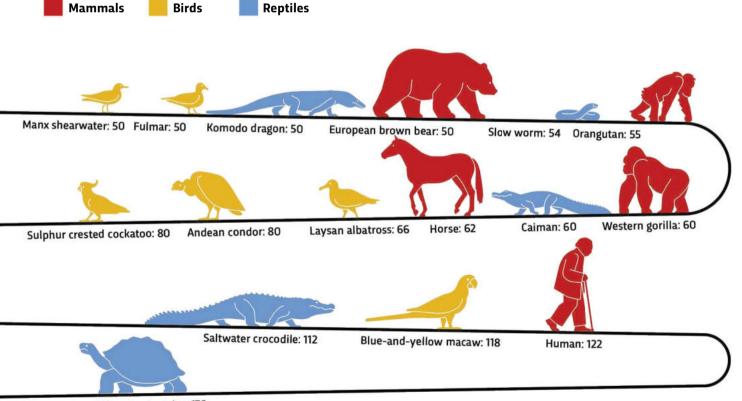
Tuatara: 100



Aldabra giant tortoise: 255

Radiated tortoise: 188

QUESTION OF THE MONTH Could you walk on a neutron star? ELLIOT WEBB, ASHFORD No. A neutron star has such an intense gravitational field and high temperature that you could not survive a close encounter of any kind. First of all, just getting onto the surface of the neutron star would be problematic. Its gravitational pull would accelerate you so much you would smash into it at a good fraction of the speed of light. Even before you arrived, the difference in gravitational pull between your head and feet would already have ripped your constituent atoms apart. Once there, though, your atomic nuclei and their free electrons would impact the surface with sufficient energy to spark thermonuclear reactions close to the super-dense surface. **WINNER!** You would become a puff of gamma rays and X-rays, as Elliot Webb wins a DNA your light elements were transformed into a cloud of ancestry kit from Living DNA heavy elements, neutrons and ultra-relativistic electrons. (£120, livingdna.com). The test Even if you were somehow magically transported onto uses a mouth swab to analyse the neutron star, therefore avoiding this energetic more than 680,000 DNA markers. impact, the million-degree temperatures at the surface breaking down your ancestry to would vaporise (and ionise) you immediately. The over 80 worldwide regions. intense gravity would then flatten what was left of you Results can be seen on



as you merged into the super-dense crust of the neutron

star. Under these circumstances, taking a leisurely walk

would be extremely difficult! AGu

an interactive online

platform.



WHAT'S IN...

...LIPSTICK?

The ingredients of lipstick need to create something that provides a glossy, smooth colour, which doesn't wipe off immediately and is considerate to a rather delicate part of the body. The major constituents of lipstick are just wax and oil, but your favourite lippy could also contain materials derived from sheep, insects, fish and hot chillis! ML

WAX

30 per cent

Often a mixture of beeswax, carnauba and lanolin (from sheep wool). Together these form the main structure of the lipstick.

OIL

65 per cent

Typically castor oil, this provides glossiness and dissolves the dyes.

DYES

5 per cent

This varies depending on the colour, but a scarlet shade might contain carmine red, which is derived from scale insects.

PLUS...

Guanine: derived from fish scales, this gives the lipstick pearlescent sheen.

Capsaicin: the chemical that give chillis their heat is added to some lipsticks to make the lips swell slightly, giving them a plumped-up look.

Are space launches bad for the environment?

Space launches can have a hefty carbon footprint due to the burning of solid rocket fuels. Many rockets are, however, propelled by liquid hydrogen fuel, which produces 'clean' water vapour exhaust, although the production of hydrogen itself can cause significant carbon emissions. Rocket engines release trace gases into the upper atmosphere that contribute to ozone depletion, as well as particles of soot. Rocket launches are nonetheless relatively infrequent, meaning that their overall impact on our climate remains much smaller than aviation's. But it's not just our immediate environment: 'space junk' is a growing concern as disused satellites and other objects accumulate in our planet's orbit. AC



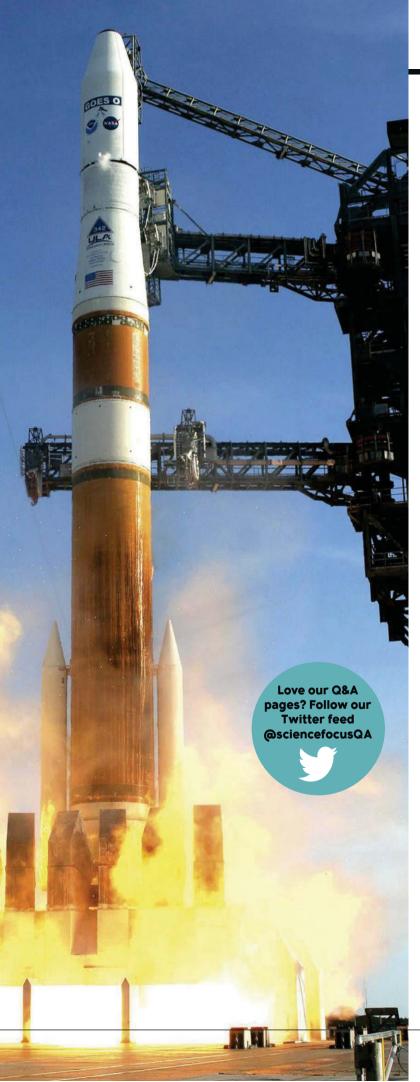
Why do planets orbit in the same direction?

VINCE GAETANO, US

This is simply the result of the initial rotation of the cloud of gas and dust that condensed to form the Sun and planets. As gravity condensed this cloud, conservation of angular momentum increased the rotational speed and flattened the cloud out into a disk.

Hence, planets that formed within this disk of material all ended up orbiting the Sun in the same direction, in almost the same orbital plane and with the same spin direction (apart from Venus and Uranus which were probably hit by other bodies, altering their spin). AGu







A lot of things can glow in the dark, including your washing powder and of course those funky stars you stick on a child's bedroom ceiling. They work through phenomena called phosphorescence and fluorescence. The material absorbs energy (usually in the form of a particular colour light) and then releases it as another colour light. Fluorescent materials do this all at once, so when you shine UV light (from a torch or the Sun) on washing powder it absorbs the UV and then emits it as blue colour (which we associate with clean clothing, which is why the washing powder people add it to the mix). Meanwhile phosphorescent materials, like glow-inthe-dark stars, do their emitting much more slowly. This enables them to shine for a few minutes after the bedroom lights are switched off. ML

Why don't we fall out of bed more often?

LOIS RUMSEY, SOUTHWELL



When we sleep, a lot goes on in our bodies. We continue to breathe and growth hormone is released – we do not need to be awake for these things to happen. Similarly, we have some awareness of our body position and movements, and some people even manage to sit up or walk during their sleep! Most of us have enough awareness to ensure that we do not fall out of bed, but this ability develops over time. Young children are still growing and understanding how their bodies fit into the world around them, which is why they might benefit from a bedrail. AGr



WHO REALLY DISCOVERED?

DNA





FRIEDRICH MIESCHER

OSWALE ΔVFRY

Francis Crick and James Watson are genetic molecule, but their work in the identification of DNA by a Swiss physician searching for the 'building blocks' of life. Friedrich Miescher had focused on proteins in cells, but in 1869 he discovered a strange substance also lurking in the nuclei of the cells. He named it 'nuclein', and suspected it would prove at least as vital to cells as proteins. Crick and Watson were not the first to show he was right, either. Their celebrated discovery of DNA's double helix structure was prompted by key experiments by a team led by the American biochemist Oswald Avery. In 1944, working at the Rockefeller University in New York, they published the results of painstaking studies using bacteria that revealed that DNA passed genetic information from one organism accepted wisdom that proteins must be the carriers of genetic information, as Crick and Watson agreed with Avery blocked by sceptics until the 1960s, by which time he was dead. RM



Francis Crick (left) and James Watson

Can eating a lot of sugar really lead to diabetes?

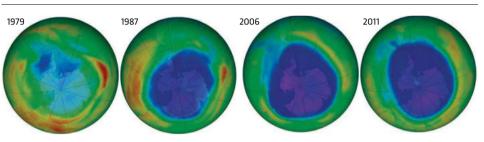
DAVID FLINT, NEWCASTLE

Yes. Too many calories of any kind will lead to obesity, which increases your chance of developing diabetes. But a 2013 study at Stanford University found that adding 150 calories of sugar per day to your diet increases your diabetes risk by 1 per cent, even after accounting for obesity, physical activity and total calorie intake. So sugar calories are particularly harmful. LU



Why is ozone depletion worse over Antarctica?

SHEILA TAYLOR, OXFORDSHIRE



Ozone depletion occurs when ozone molecules in the upper atmosphere are destroyed by chemical reactions with halogen gases, such as chlorine. Cold conditions above Antarctica in the winter months encourage the formation of extremely cold, high-altitude clouds. These clouds provide the ideal conditions for chlorine that was

previously trapped in stable molecules to be transformed into highly reactive chlorine gas, which accumulates over the long polar night. As winter ends, sunlight breaks apart the chlorine gas molecules, freeing billions of chlorine atoms, which go on to react with ozone molecules, causing a sharp dip in ozone levels: the ozone 'hole'. Ac

Why does depression make you dream more?

MARY BENSON, LUTTERWORTH



People suffering from depression may experience unusual patterns of sleep. Typically, they move into REM sleep (the stage in which we are most likely to dream) more quickly, and there may be a greater number of eye movements per unit of time during this stage of sleep. People who are depressed may wake up more frequently during the night, and are therefore more likely to remember their dreams. Finally, there is some evidence that certain medications for depression can increase the frequency of nightmares. Other medications appear to do the opposite, but nightmares can occur during withdrawal from these drugs. Agr





Why do bolognese, stews and curries taste better the next day?

ALINE COOPER, CHELMSFORD

Collagen in meat breaks down into gelatine at temperatures between 71 and 96°C. A stew that's been bubbling on the stove will continue to break down its collagen for half an hour after you take it off the heat. In the fridge, this will set to a firm jelly and when you reheat it, the gelatine melts to create a silky feel in the mouth. Tomatoes also benefit from long and slow cooking to release flavour molecules within the skin, and a speedy mid-week spag bol won't have time to reach peak tastiness until it has had those extra hours to marinade. Free water

in a dish will tend to soak into starch, taking dissolved flavour with it – pea and ham soup tastes better the next day because the ham stock has been absorbed by the pea starch.

But there's a psychological aspect too. Chef and food writer James Kenji López-Alt tried to perform scientific comparisons and found little difference when tasting fresh and day-old dishes side-by-side. Perhaps we get habituated to the cooking smells the first time round, and things taste better with a clear nose the next day. IV



Why is red light used on submarines?

JOHN AWBERY, READING

The human eye is less sensitive to longer wavelengths, so red light is chosen to preserve the night vision of the crew while still allowing them to still see their instrument panels. Submarines switch to red light when it's dark outside and crew members need to use the periscope or go on watch duty. RM

WHAT CONNECTS...

...SMILING AND LONG LIFE?



probably
evolved from
displays of
social submission.
Chimpanzees make a
smiling face when they are
afraid. In humans this may
have later evolved into an
expression to diffuse
aggressive encounters.

Smiling

Now that smiling indicates a positive mood, it's also correlated with reduced stress hormones and blood pressure. Numerous shave linked both of the

pressure. Numerous studies have linked both of these to your chances of having a heart attack.



Marriage also lowers your heart attack risk and a 2009 study found that people who frown in college yearbook photos are five times more likely to get a divorce than

those who smile.

And overall, smiling correlates with good health. Researchers who looked at photos of 230 baseball professionals from the 1950s found that the players with the

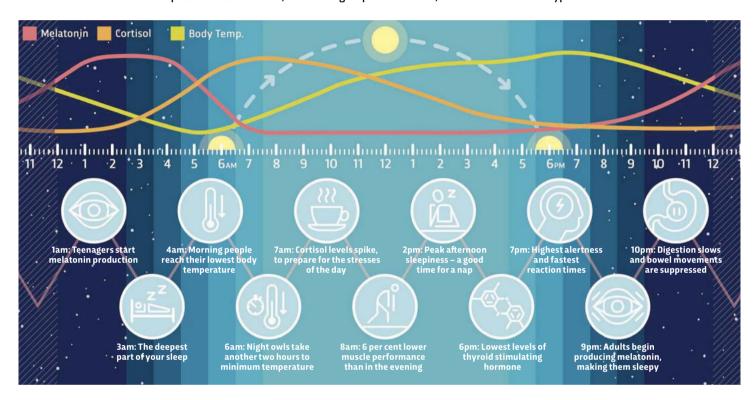
found that the players with the most genuine smiles tended to live the longest.

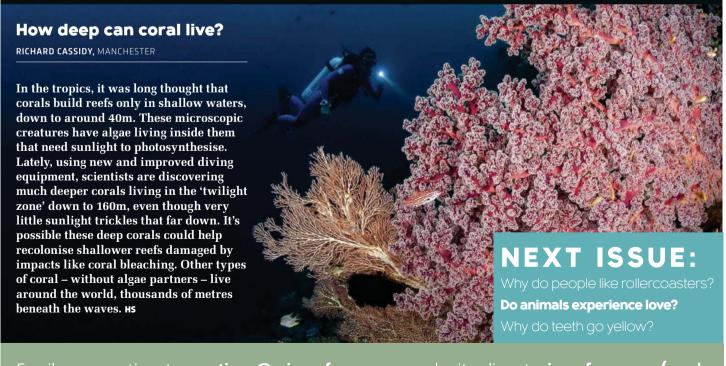


HOW IT WORKS

CIRCADIAN RHYTHMS

As we are primarily active during daylight hours, our bodies have evolved a schedule for different metabolic processes to make sure we use energy in the most efficient way. Muscle performance and reaction times are optimised during the day, while tissue repair and memory formation are handled during our downtime. The circadian rhythms are the 24-hour cycles of each part of our body. They are controlled by the fluctuating levels of different signal molecules in our cells – known collectively as biological clocks. All the clocks are synchronised by a master clock in our brain called the suprachiasmatic nucleus, which is a group of around 20,000 brain cells in the hypothalamus.



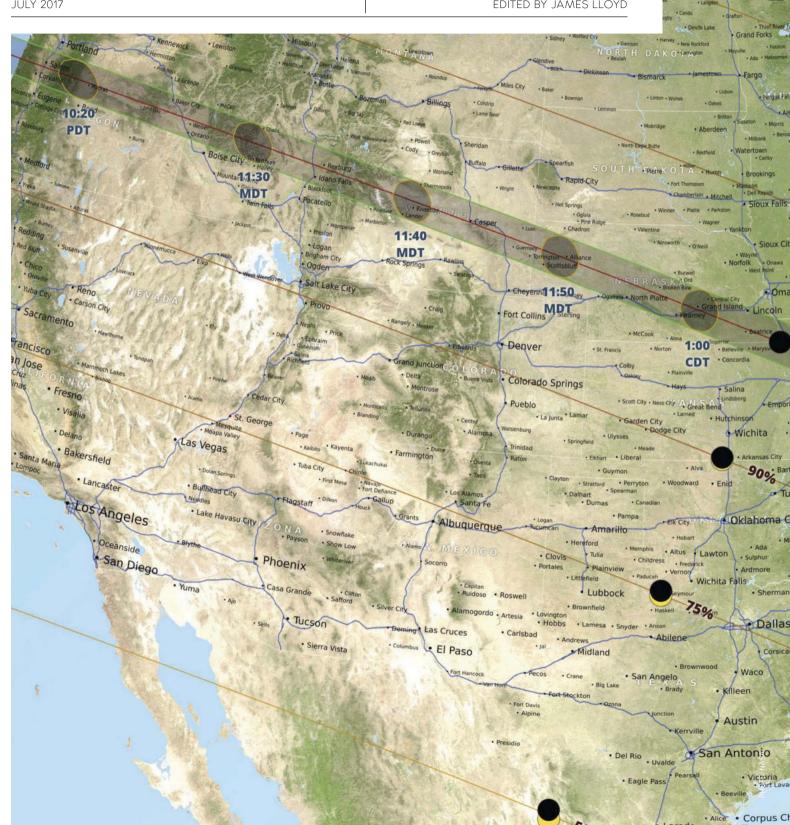


Email your questions to questions@sciencefocus.com or submit online at sciencefocus.com/qanda

OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

EDITED BY JAMES LLOYD JULY 2017





O MEET THE PLANT MESSIAH

CARLOS MAGDALENA is on a mission to save the plants. From his base at Kew Gardens, he travels the world to rescue tropical species from extinction. The botanical horticulturalist talks to JAMES LLOYD

What started your love of plants?

I grew up in northwest Spain, in a region called Asturias on the Bay of Biscay. This is an incredibly biodiverse place, with the largest patch of primary deciduous forest in Europe, plus populations of wolves and brown bears! But it was also becoming one of the most industrialised areas in Spain. Within 30km, I could go from a lush, green world to a place of total destruction. I was fascinated by this contrast from an early age.

How did you end up working at Kew?

I didn't have any formal qualifications in horticulture, but I managed to secure an internship in the Tropical Nursery. I enrolled on the three-year Kew Diploma in



2003, and over the next few years I began to earn a reputation for saving endangered tropical plants.

The 'Plant Messiah' nickname was given to me by a journalist in Spain, who obviously thought that I looked a bit like Jesus! But don't worry, I don't actually have a Messiah complex...

How do you actually go about saving a plant from extinction?

Sometimes saving a plant is as easy as taking a cutting from it, or collecting some fruits. The hard part is often the political bureaucracy. Once you've found a plant that's endangered, you need to convince the country's government to let you come and take a cutting, and then you have to get the plant safely back to the UK so that the science can begin.

Around 20 per cent of plant species are currently threatened with extinction. There are nearly 400,000 species of plants known to science, so saving all of them is a titanic task – we need a whole army of Plant Messiahs.

What's been the proudest moment of your career so far?

It's been saving the café marron plant. This gorgeous shrub has glossy green leaves and snow-white flowers, and it's native to the island of Rodrigues in the Indian Ocean.

Carlos Magdalena examines a specimen of *Nymphaea thermarum* – the world's smallest water lily







The plant was thought to be extinct, but in 1980 a schoolboy found a specimen by the side of a road. Kew managed to grow cuttings from it, but the flowers weren't producing the seeds necessary for it to survive in the wild. No one knew why; it became known as the 'living dead'.

I became totally obsessed with this plant. By the time I arrived at Kew in 2003, there were several specimens of café marron, all from the same parent cutting. They were constantly producing flowers, which gave me lots of opportunities to try different things. Eventually, I developed a way to transfer the pollen between flowers, pollinating the plants at relatively high temperatures so that they produced fruit and seeds. Over the course of a year, 300 seeds were harvested in total, and we could reintroduce the species into its native habitat.

Does it really matter if a plant like the café marron goes extinct?

Everything has a knock-on effect. We know that this plant is pollinated by moths, which could also be endangered. By protecting one plant, we're protecting an entire ecosystem. It's like a plane flying at high altitude. We can remove the seats, the toilet, the carpets, and nothing much will happen. But we don't know which extinction is going to be the one that removes the engine and brings the whole thing crashing down.

Why do you think plant extinctions get so much less media coverage than animal extinctions?

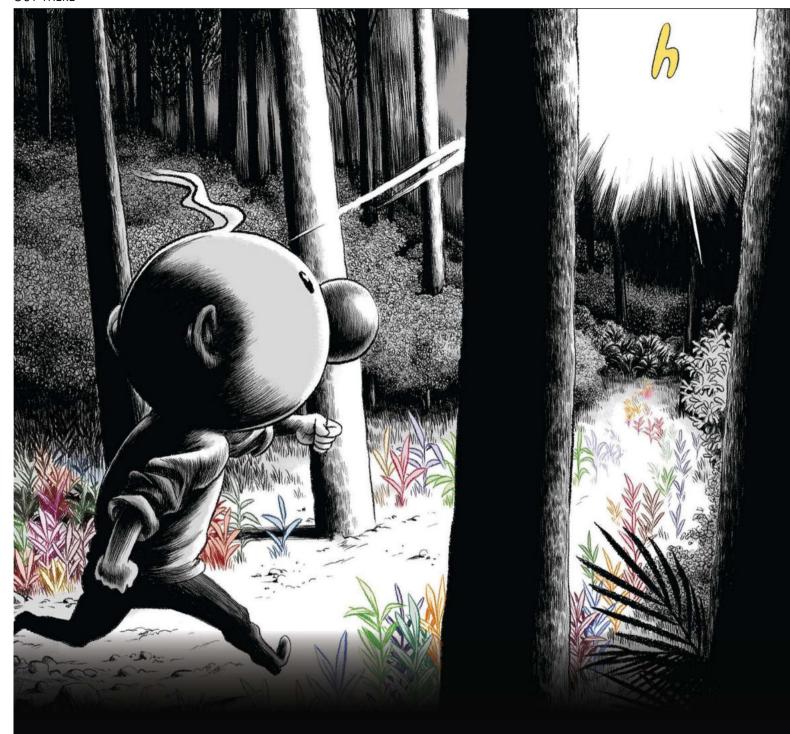
We suffer from plant blindness. If we're shown a picture of a monkey in a rainforest, we'll see the monkey but not the trees. Plants don't run or fly; they don't have fur or make funny noises, so we find it harder to feel for them. But economically, plants are more important to us than most animals. We depend on them for our clothes, medicines, food, building materials, oxygen, and so much more. Money really does grow on trees.

What's next on your list of plant species to save?

There's this palm on Mauritius that's known as 'the loneliest tree on the planet'. The species was once widespread, but there's now only one left in the entire world. We haven't been able to grow it at Kew so far, but I'm confident we can do it.



THE PLANT MESSIAH
BY CARLOS MAGDALENA
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EXPLORE THE QUANTUM UNIVERSE

Quantum physics is notoriously difficult to explain, but help is at hand! In new graphic novel, *Mysteries Of The Quantum Universe*, explorer Bob and his dog Rick take us on a journey through the world of the very small. Led by their tour guide, the letter h (also known as the Planck constant), they talk atoms with Einstein, visit Louis de Broglie in his castle, and hang out with Heisenberg on Heligoland.

Billed as 'Tintin meets Brian Cox', the book was created by theoretical physicist Thibault Damour and illustrator Mathieu Burniat, so it's as scientifically accurate as it is beautiful.



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04

TOMORROW'S WORLD

BBC.CO.UK/TOMORROWSWORLD

WELCOME BACK, TOMORROW'S WORLD...

Readers of a certain age will remember the long-running TV show *Tomorrow's World* (paper underwear! snookerplaying robots!), and now it's returning, albeit under a different guise. The BBC has resurrected the name for a year-long celebration of science and technology, featuring podcasts, radio series, short films, citizen science experiments and more than 40 hours of new TV.

TV highlights include *Britain's Greatest Invention* (BBC Two, June), in which Dr Hannah Fry and Ant Anstead put our country's greatest inventions to a public vote, while in *Expedition New Earth* (BBC Two, summer) Prof Stephen Hawking explains his prediction that the human race only has 100 years before we need to find another planet. Meanwhile, *The Toughest Job In The Universe* (BBC Two, summer) follows 12 men and women as they embark on the training programme usually reserved for real-life astronauts, and we'll also be treated to new series of *How To Stay Young* and *Trust Me, I'm A Doctor*. Stay tuned for continuing coverage of the season!

05

AEROSPACE BRISTOL OPENS SUMMER 2017

AEDOSDACERDISTOI ODO

...AND CONCORDE

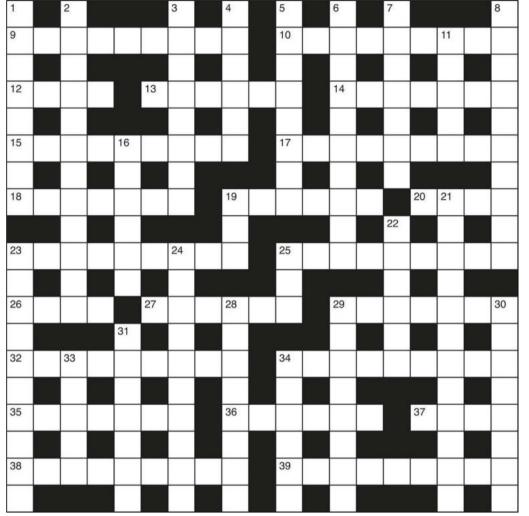
In what's proving to be a month of comebacks, Bristol has welcomed Concorde to a new purpose-built hangar that will soon be opening to the public. Concorde 216, which was the last of the supersonic jets to fly before the fleet was retired in 2003, will form the centrepiece of a new museum celebrating the region's aerospace industry.

Opening in summer 2017, Aerospace Bristol will tell the story of more than 100 years of aviation history, from the earliest days of the Bristol Boxkite (one of the first planes produced in large numbers) through to the two world wars, the technological leaps of the space race and today's ultra high-precision engineering.



BBC FOCUS CROSSWORD

GIVE YOUR BRAIN A WORKOUT



DOWN

- 1 Speculator at home upsets voters (8)
- 2 Honest range includes one-dimensional object (8,4)
- 3 Furious wolf runs and ducks, say (8)
- 4 Take chants away (6)
- 5 Scale for use outside (8)
- 6 His contributions are always late (10)
- 7 Weep, having gone off freezing mixture (7)
- 8 Gossips on value of Derbyshire mansion (10)
- 11 Badly reign part of Africa (5)
- 16 Tenner wasted on cheese ingredient (6)
- 19 Turn up second form of secretion (3)
- 21 He's careening about in program (6,6)
- 22 Gilding in refurbished room left to university (6)
- 23 Gloomy note rewritten in study (10)
- 24 Noble dummy flourished in his element (10)
- 25 Join a religious man (3)
- 28 For every stretch of river, put in a missionary (8)
- 29 Use of old style has strange charisma (8)
- 30 Confine alien in web (8)
- 31 Arab commando's payment includes energy and time (7)
- 33 Fast old tempo (5)
- 34 Zen enlightenment as riot breaks out (6)

ACROSS

- 9 Fool has share in conversion of organic compound (9)
- 10 Bar thinly spread out in maze (9)
- 12 Cheese additive encounters barrier (4)
- 13 Chief rioted unexpectedly (6)
- 14 The missing conclusion should be an idea (7)
- 15 Insect that flew in WW2 (5,4)
- 17 Frightening figure races round to boast (9)
- 18 Vitamin has role to play with metal (7)
- 19 In favour of healthy gain (6)
- 20 New arts supremo (4)
- 23 Prise dime out of layer of skin (9)

- 25 Resulting situation following American subject (9)
- 26 Ash, say, found in street (4)
- 27 Plead to play with one bat, say (6)
- 29 A sofa, initially indulging rodent (7)
- 32 Easily influenced, blame all change to energy (9)
- 34 Cactus, say, that's good to eat (9)
- 35 Family row takes time (7)
- 36 Chat about a year in old China (6)
- 37 Ottoman ruler registered for a laxative (4)
- 38 Spore cluster makes giddy mogul reel (9)
- 39 One's crane turned out to have special meaning (9)

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**Please be aware the

website address is case-sensitive.





"Bandits must've seen our car on the crater rim; two guys with a rifle and a machete turned up"

This month, volcanologist Prof Tamsin Mather talks to Helen Pilcher about getting up close and personal with one of nature's most destructive forces

Why study volcanoes?

They are a spectacular natural phenomenon. They can be hazardous, but they can also be a positive force. Because they're so big they can change rainfall patterns. They provide resources like mineral deposits. They're tourist attractions. They're also a key force in shaping not just our Earth, but other planets too.

Which volcanoes are the most explosive?

It depends on the magma and the gases trapped in it. Some, like those in the Pacific Ring of Fire, have sticky, viscous magma that traps gas at high pressures, leading to really big explosions. Others, like the ones on Hawaii, have runnier magma so trapped gases can escape more easily. So you end up with lava flows that look spectacular but that don't tend to kill many people.

Is your work dangerous?

Volcanoes can be dangerous for lots of reasons, not just their eruptions. These are big mountains. One time, I was on Mount Etna when the weather changed suddenly. It started snowing and hailing and we got really blown around. I was pretty nervous, but fortunately our guides were able to get us down safely. No measurement is worth risking your life for. It can be a lot of fun though.

How so?

The science is fascinating, the scenery is breathtaking and sometimes it can be surreal. When I worked on Villarrica volcano in Chile, we'd spend the day taking measurements at the summit, then strap our equipment to our backs and slide down the snowy ice cap on our bums.

What's it like getting so close to an active volcano?

It's pretty intense. If you're standing in a volcanic plume, the smell can be horrible. There's sulphur dioxide, which smells of burnt matches, and hydrogen sulphide, which reeks of rotten eggs. There are also various acids, which make your skin feel really unpleasant.

Do you need any special gear?

Some volcanoes are not easy places to be. You need a gas mask, helmet and eye protection. Sturdy boots. And synthetic clothes are better than natural cotton. The gases can eat through cotton trousers. You take them home and wash them, then find that they are full of holes.



What's the scariest experience you've had on a volcano?

I was held up at gunpoint on Masaya volcano in Nicaragua. We were so excited about taking measurements that we went to the national park before the rangers arrived and it had officially opened. Some local bandits must have seen our car on the crater rim, so two guys with a rifle and a machete turned up. They were a bit confused when we didn't have any money just scientific equipment. In the end they just took a

camera and a watch, but it was pretty nerve-racking.

Can you pronounce the name of

Prof Tamsin Mather is professor of earth sciences at the University of Oxford, specialising in volcanology and atmospheric chemistry.

DISCOVER MORE



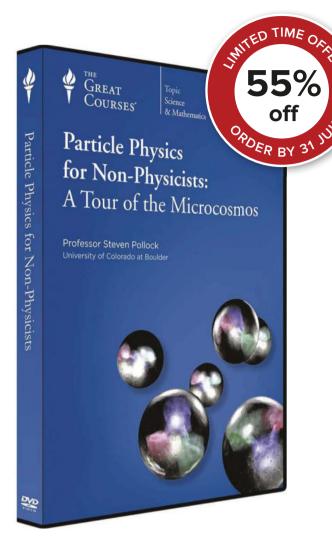
To listen to episodes of The Life Scientific with top scientists visit bit.ly/life_scientific

NEXT ISSUE: JANE FRANCIS

'that' Icelandic volcano? Evjafjallajökull? Yes, I can,

although not perfectly. It annoyed lots of people in 2010 when its ash clouds closed airports. I was on maternity leave at the time and got loads of phone calls from journalists, so it disrupted my life in a different kind of way. •





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- 12. From Quarks to QCD
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